MONITORING OF R-2000 LOW ENERGY HOUSES

1986

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MONITORING OF R-2000 LOW ENERGY HOUSES

SUMMARY TO THE JUNE, 1986 REPORT

Background

The Ontario Ministry of Energy established this monitoring project to determine the performance of twenty-two R-2000 homes built in the 1983 to 1985 period in Ontario.

The R-2000 Home Program is a cooperative government/industry initiative which began in 1982. It is funded by the Federal Department of Energy, Mines and Resources (EMR) and is administered across Canada by the provincial offices of the Canadian Home Builders' Association (CHBA).

R-2000 is a recognized standard for practical low energy new housing in Canada, a standard based on energy performance which allows for flexibility in design.

CHBA, or its provincial member designate, approves R-2000 house plans at the design stage, using the HOTCAN (now HOT-2000) heat loss simulation program. R-2000 houses are certified only after the design and construction have passed a series of inspections. In addition, certain construction techniques and mechanical equipment must conform to R-2000 guidelines.

In the context of this monitoring project, four builders were involved. Three are low volume custom builders situated in smaller urban centres. The fourth builder is a large contractor, building several hundred homes a year in a larger, suburban metropolitan area.

To date, the Ministry has assisted these and other R-2000 builders with training, design, marketing and initial demonstration projects.*

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* This assistance is in addition to that offered by EMR under the R-2000 Program.

Rationale

The monitoring project was designed to determine the following information about R-2000 houses:

- How much energy does an R-2000 house use? How does this total compare with the total from a conventional house, of equal size, in the same climate? How does actual R-2000 energy use compare with HOTCAN computer predictions?
- Do R-2000 houses, with their low air leakage rates, have acceptable air quality?
- Do R-2000 builders produce reliable, durable houses, free from moisture problems?
- Do R-2000 builders produce houses which are comfortable, in all weather conditions?
- Are R-2000 owners satisfied with their houses?

In order to answer these questions, the Ministry entered into an agreement with a qualified monitoring contractor. The contractor has been monitoring the above mentioned twenty-two R-2000 houses, as well as five comparable, new, standard construction houses, since July, 1985.

Methods

The following information has been collected at each house on a monthly basis.

- energy consumption (total house, total space heating, and total domestic hot water);
- homeowner attitudes and behavour;
- construction reliability;
- air quality (formaldehyde, carbon dioxide, carbon monoxide, radon);
- airtightness of the house structure;
- heat recovery ventilator operation, and flow rates;
- detailed computer monitoring (4 houses only).

The main body of the monitoring report details these and other tests.

The Ministry budgeted $247,000 (Cdn) for the first year of the monitoring project, including purchase and installation of instruments. The monitoring project started in July, 1985, with the majority of the monitoring instrumentation completed during the first three months.

Results

The smaller, custom builders, building single family detached R-2000 designs, encountered few problems in meeting R-2000 Program inspection requirements.

The larger builder in the metropolitan area selected an 82 unit townhouse development as its first R-2000 project. The builder also met all R-2000 Program inspection requirements. However, the builder did encounter a unique set of problems associated with the management, supervision and control of area trades who were largely unfamiliar with R-2000 construction practices.

Results relating to energy, owner satisfaction, construction reliability, air quality and ventilation in the houses were as follows:

Energy:

The R-2000 houses consumed an average of 37% of the annual space heating energy, per square metre of floor area, of typical new houses in Ontario. Twelve of the 22, R-2000 houses consumed less energy for space heating than for the total of lights, appliances, and hot water.

However, the R-2000 houses consumed an average 45% more space heating energy than was predicted by the HOTCAN computer program. Eleven of the R-2000 houses consumed more than 150% of their HOTCAN predictions (refer to figure 1).

Reasons for greater-than-predicted space heating energy consumption included:

- air leakage around structural joints;
- conduction heat losses along joints between concrete foundations and brick walls, and from uninsulated concrete party walls in the attic spaces of row houses;
- addition of extra architectural features (e.g. skylights, fireplaces) by the builders, after HOTCAN approvals had been obtained; and,
- improper location of some heating registers, causing homeowners to increase thermostat settings.

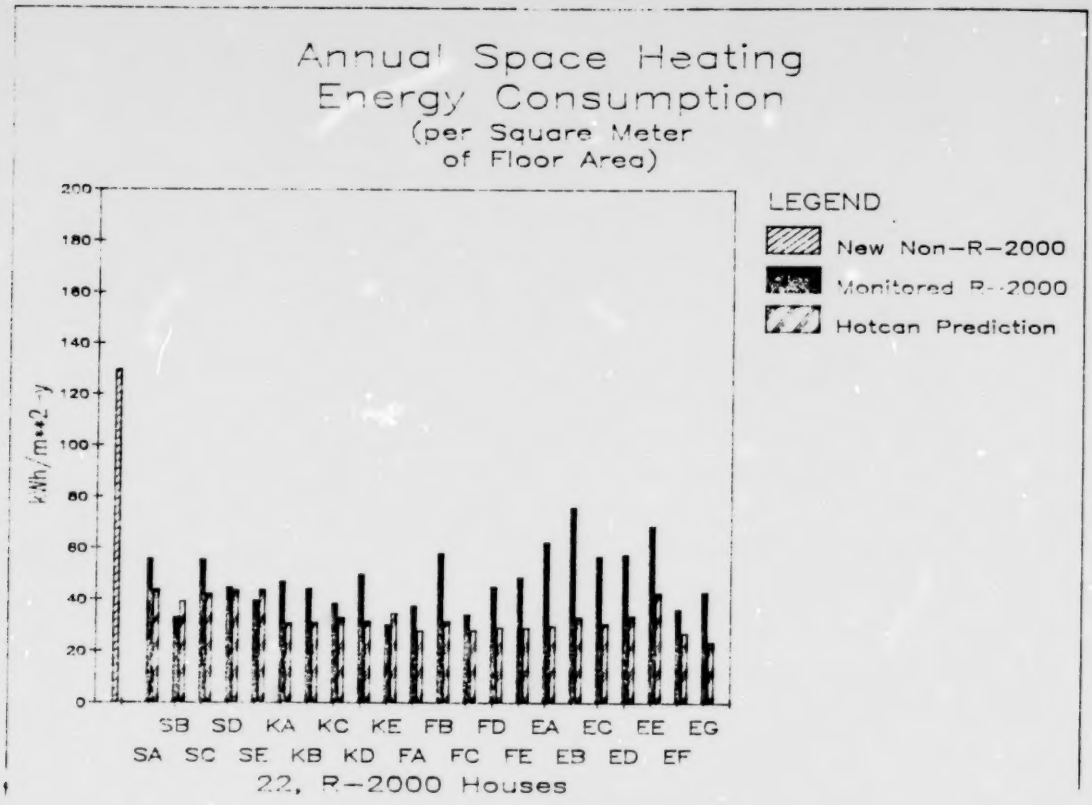


Figure 1

Owner Satisfaction:

Thirteen out of the twenty-two R-2000 homeowners (59% of the total) said that they would buy another R-2000 house, if they were in the market for a new house. This survey was conducted in March, 1986.

Specific complaints included dust in some of the houses, and air distribution problems.

Some of the house bathrooms were uncomfortable, because of improper location of heating registers, along warm interior walls, away from cold windows and exterior walls. This improper location of registers is of special concern in an R-2000 house, where, in general, the small central heating furnace cannot always compensate.

Construction Reliability:

Close inspection and infra-red thermography showed that none of the R-2000 houses encountered moisture damage or structural problems. One house had a basement moisture problem, which was not related to its R-2000 design.

Air Quality:

Tests of the 22 R-2000 houses and 5 non-R-2000 houses failed to detect any significant contamination by formaldehyde, radon, carbon monoxide, or carbon dioxide, during eight months of monitoring. Measured contaminant levels from the R-2000 and non-R-2000 houses were well within recognized guidelines, and were typical for housing in general. The only air contaminant mentioned by homeowners was dust, which may be typical for new buildings.

Ventilation:

Heat recovery ventilators and their accompanying duct systems did not meet the R-2000 requirement of 0.45 air changes per hour in 18 of the 22 houses. In spite of this deficiency, the air quality in these houses, as noted above, was well within recognized guidelines. The lowest measured number of air changes per hour was about 60% of the requirement. In most of the R-2000 houses, the flow rates for fresh air vs. exhaust were not balanced.

Some of the heat recovery ventilators experienced operational problems, involving defrosting of the heat exchangers during winter weather.

All of the heat recovery ventilators and duct systems will be brought up to R-2000 requirements by the end of 1987 in a separate project.

The heat recovery ventilators operated with average effectiveness between 50% and 80%, in recovering heat from exhaust air, as expected.

Conclusions

Based on the sample in this project, the first year of monitoring has proven the basic integrity of the R-2000 Program in Ontario. R-2000 houses are energy efficient, have no air quality problems, and are solidly built. The monitoring project revealed some outstanding examples of practical, comfortable, marketable, Canadian low energy housing.

However, some of the R-2000 houses experienced problems with heat losses and air distribution. The monitoring contractor was able to trace these problems to inconsistencies in design, construction techniques, and inspection.

An R-2000 house requires consideration of energy in all aspects of design and construction. Typical trade practices (e.g. installation of ducts and heating registers) must be improved to match the requirement for comfort with the low energy flows in an R-2000 house. Additional architectural features (e.g. skylights) must not be added to an R-2000 house without regard to their effect on the overall energy requirements.

The R-2000 Program is improving and refining both its standard and its certification procedure. Hopefully, R-2000 design and inspection practices should improve, as experience is gained, so that previous problems are not repeated.

The Ministry intends to continue the R-2000 monitoring project until June, 1988. Monitoring of the same R-2000 houses over three years will show any changes in their energy performance. Five more new R-2000 houses are being added to the project in the next phase of monitoring.

1.0 INTRODUCTION

Buchan, Lawton, Parent Ltd., under contract with the Ontario Ministry of Energy, is undertaking an investigation of R-2000 houses built under the Affordable Low Energy New Housing Program.

The monitoring program is intended to investigate four specific areas. These areas are:

- the energy performance of the houses,
- the quality of the internal environment,
- the level of homeowner satisfaction, and
- construction reliability.

This report details the work undertaken and the results obtained during the initial phase of the monitoring program commencing in September 1985 and ending June 30, 1986.

1.1 Description of the Monitoring Program

The monitoring program involves twenty two R-2000 houses. Fifteen of these were built under the Ministry's Affordable Low Energy New Housing Program in 1983 and 1984 in three communities: Sudbury, Kingston, and Fonthill. The remaining seven R-2000 houses are part of an eighty two unit townhouse development in Erin Mills (Mississauga), funded jointly by Energy, Mines and Resources Canada and the Ministry in 1985. These four communities were chosen in order that the monitoring span the range of climatic conditions experienced by R-2000 homes built under the programs.

The inspection and certification of the R-2000 houses built under the Affordable Low Energy New Housing Program was undertaken by the Canadian Home Builders' Association on behalf of the Ministry. The inspection and certification of the Erin Mills houses was undertaken by the Ontario Home Builders' Association on the behalf of Energy, Mines and Resources Canada.

As well as the twenty two R-2000 homes involved in the monitoring program, there are five control homes from which background data is also gathered.

All twenty two R-2000 houses included in the monitoring program have been extensively tested to characterize each individual house. The details of the test program are included in Section 2.0 of this report.

Energy data is gathered from each house in order to generate energy use profiles on a month by month basis which can be compared with HOTCAN predictions for each house. Submetering data is collected in order to individually measure energy for space heating and energy for dometic hot water production. The results of the energy analysis program are detailed in Section 3.0 of this report.

The monitoring of the indoor environment in each house consists of the measurement of the concentrations of four specific indoor pollutants:

- formaldehyde,
- radon,
- carbon dioxide, and
- carbon monoxide.

The results of the indoor air quality analysis portion of the monitoring program are discussed in Section 4.0 of this report.

One house in each of the communities where monitoring is being undertaken was selected for detailed monitoring with the use of a computerized data acquisition system. The computerized data acquisition systems are designed to continuously monitor and record temperatures and humidities throughout the house as well as the operation and the status of major mechanical systems in each house.

The detailed monitoring portion of the program particularly emphasizes the performance monitoring of the heat recovery ventilator (HRV) system. The results of the detailed monitoring program are discussed in Section 5.0 of this report.

Through the use of homeowner interviews, detailed questionnaires were filled out to produce profiles of the occupants of the houses being monitored and to provide a mechanism for the feedback of homeowner concerns and comments about the performance of their house. Additional information as to homeowner concerns is continually gathered through ongoing contact with each homeowner. The results of this portion of the monitoring program are discussed in Section 6.0 of this report.

The monitoring program has involved monthly visits to each house by Buchan, Lawton, Parent Ltd. personnel. At that time, energy data is collected, air quality samplers are deployed and specific tests of the house are undertaken. The specific house testing carried out during each monthly visit varies throughout the monitoring program based on a pre-determined schedule designed to have specific tests carried out under the most appropriate climatic conditions.

A profile of each R-2000 house in the monitoring program is included as Appendix A of this report. The profiles include a basic description of the house and its mechanical systems, a profile of the occupants of the house, and specific monitoring data.

2.0 HOUSE TESTING

Extensive testing of the twenty two R-2000 houses being studied in this project has been carried out. The major tests performed included:

- fan depressurization testing,
- thermographic scanning,
- combustion appliance backdraft testing,
- sound level testing,
- ventilation capacity testing,
- combustion appliance efficiency testing,
- air distribution system balance testing.

2.1 Depressurization Testing

The twenty two R-2000 houses were tested using the CGSB Draft Standard CAN2 149.10 M85, 11th Draft, to determine the air leakage characteristics of the building envelope. Table 2.1.1 presents the results of the testing in terms of air changes per hour at a 50 pascal pressure difference across the building envelope and the equivalent leakage areas (ELAs). Some of the twenty two houses in the sample were tested twice; first, they were tested with envelope penetrations closed in the manner described in the CGSB Standard and then were re-tested in the manner described below.

During depressurization testing and in discussions with occupants, it was found that some of the fireplace fresh-air inlets, particularly in the houses in Erin Mills, did not seal properly. In view of the fact that these sealing problems were on the list of deficiencies to be remedied by the builders, the dampers were temporarily taped to better seal the opening. Therefore, in these instances, the results of the two sets of tests are presented in Table 2.1.1. The difference in the test method is indicated in this table by identifying the fireplace combustion air inlet as sealed or unsealed. All testing was performed using Buchan, Lawton, Parent Ltd.'s Retrotec door fan which was most recently calibrated in August, 1985. Figure 2.1.1 is a histogram of the air leakage test results.

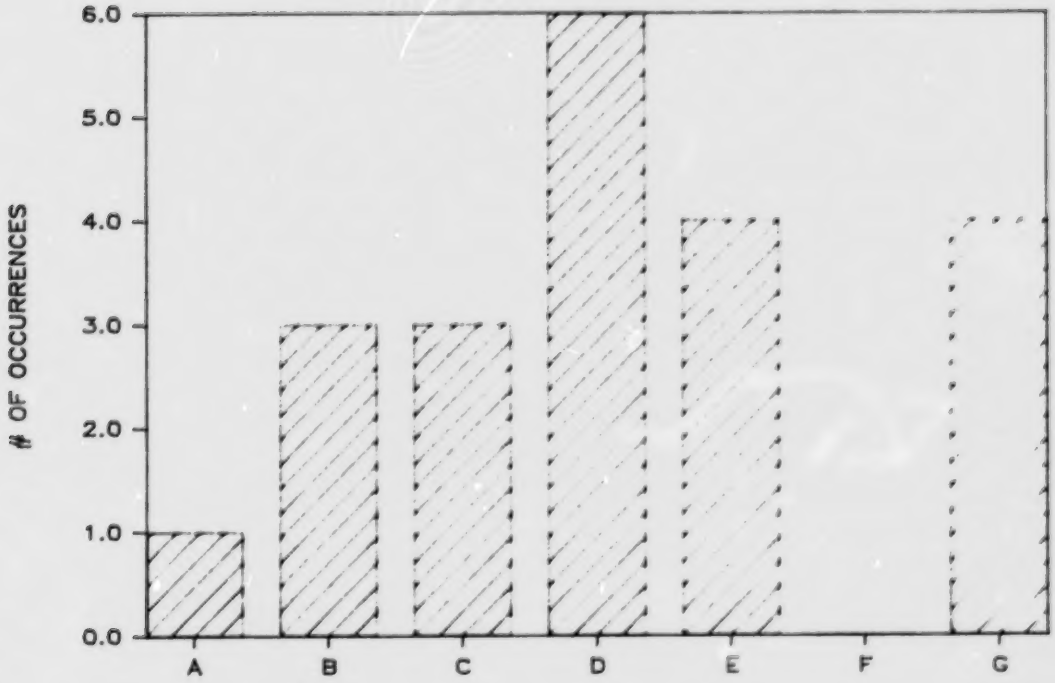
Table 2.1.2 presents a comparison between Buchan, Lawton, Parent Ltd.'s testing and the original testing for qualification under the R-2000 program. As can be seen in the testing, some increase in air leakage has occurred in most houses in the months since the original testing. Most of the houses still meet, or are relatively close to meeting, the R-2000

TABLE 2.1.1 DEPRESSURIZATION TEST RESULTS

	Manufacturer of HRV Unit	House Volume (cu.m.)	No. of Fire-places	Fireplace Sealed**		Combustion Air Inlet Unsealed**	
				ACH (@ 50 Pa)	ELA	ACH (@ 50 Pa)	ELA
SUDBURY							
House A	Air Changer DR150	495	1	1.293	0.022	1.34	0.025
House B	Nutone AE200	450				0.883	0.012
House C	Nutone AE200	492				1.121	0.019
House D	Air Changer DR150	485				1.248	0.019
House E	Air Changer DR150	494	1			1.528	0.032
KINGSTON							
House A	Air Changer DR150	682	1			1.506	0.037
House B	Air Changer DR150	621	1			1.341	0.028
House C	Air Changer DR150	647	1			1.782	0.04
House D	Air Changer DR150	521	1			1.415	0.028
House E	Air Changer DR275	682	1			1.235	0.032
FONTHILL							
House A	Air Changer DR275	696	1			1.883	0.049
House B	Air Changer DR150	518	1			2.373	0.043
House C	Air Changer DR150	580	1	1.667	0.031	1.707	0.033
House D	P.M. Wright WR25	679	1			1.695	0.041
House E	Air Changer DR150	573	1	1.862	0.036	1.886	0.037
ERIN MILLS							
House A	Lifebreath 250	548	2			2.514	0.049
House B	Lifebreath 250	548	2	2.269	0.045	2.544	0.054
House C	Lifebreath 250	548	2	2.421	0.05	2.521	0.053
House D	Lifebreath 250	572	1	1.835	0.038	1.99	0.036
House E	Lifebreath 250	599	1			1.739	0.034
House F	Lifebreath 250	517	1	1.59	0.03	1.666	0.03
House G	Lifebreath 250	517	1	1.646	0.03	1.703	0.031
	AVERAGE	568			AVERAGE	1.711	0.035

Notes:
** Preparation of the fireplace combustion air inlet.

AIR LEAKAGE TEST RESULTS



LEGEND

A	less than 1.00 ACH at 50 Pa.
B	between 1.00 and 1.24 ACH at 50 Pa.
C	between 1.25 and 1.49 ACH at 50 Pa.
D	between 1.50 and 1.74 ACH at 50 Pa.
E	between 1.75 and 1.99 ACH at 50 Pa.
F	between 2.00 and 2.24 ACH at 50 Pa.
G	greater than 2.25 ACH at 50 Pa.

FIGURE 2.1.1

TABLE 2.1.2 DEPRESSURIZATION TEST RESULTS
Changes Since Original Post-Construction Depressurization Test

	Manufacturer/ HRV Unit	House Volume* (cu.m.)	Original Test Results ACH (@ 50 Pa)	BLP Testing Nov/Dec 1985 ACH (@ 50 Pa)
SUDBURY				
House A	Air Changer DR150	495	0.62 **	1.34
House B	Nutone AE200	450	0.52 **	0.883
House C	Nutone AE200	492	0.97 **	1.121
House D	Air Changer DR150	485	0.82 **	1.248
House E	Air Changer DR150	494	0.97 **	1.528
		AVERAGE	0.78	1.224
KINGSTON				
House A	Air Changer DR150	682	1.37 **	1.506
House B	Air Changer DR150	621	1.22 **	1.341
House C	Air Changer DR150	647	1.34 **	1.782
House D	Air Changer DR150	521	1.30 **	1.415
House E	Air Changer DR275	682	1.03 **	1.235
		AVERAGE	1.252	1.4558
FONTHILL				
House A	Air Changer DR275	696	1.22	1.883
House B	Air Changer DR150	518	1.41	2.373
House C	Air Changer DR150	580	1.44	1.707
House D	P.M. Wright WR25	679	1.46	1.695
House E	Air Changer DR150	573	1.48	1.886
		AVERAGE	1.402	1.9088
ERIN MILLS				
House A	Lifebreath 250	522	1.45	2.64
House B	Lifebreath 250	527	1.53	2.65
House C	Lifebreath 250	527	1.51	2.62
House D	Lifebreath 250	522	1.48	2.18
House E	Lifebreath 250	574	1.44	1.81
House F	Lifebreath 250	579	1.45	1.80
House G	Lifebreath 250	579	1.47	1.84

Notes:
* As indicated on HOT2000 run or as measured by BLP
** Corrected Air Change rates; some of the original ACH calculations did not use the house volumes indicated on the HOT2000 test run, data has been corrected to express ACH's in terms of the HOT2000 house volumes.

standard of 1.5 air changes per hour at 50 pascals. The notable exceptions are House B in Fonthill and Houses A, B, C and D in Erin Mills.

In Erin Mills, Houses A, B, C and D (the first block of R-2000 condominiums constructed) appear substantially different from the final block of R-2000 condominiums as indicated by the test results for Houses E, F and G. A complete explanation is not available for this difference in air-tightness between the first block and the final block of condominium units (the first block averages 40 percent more air leakage than the final block). A factor that must be considered when comparing the two blocks is that the test method used for the originial test on the first block was to pressurize rather than depressurize the units. This was done because the drywall was not yet in place.

2.2 Thermographic Testing

The thermographic scanning of a building envelope provides a useful method of determining areas of heat loss due to conduction and areas where substantial air leakage is occuring.

Complete thermographic scans were undertaken on two separate occasions in November 1985 and in February 1986.

During the November 1985 testing, the houses were examined for thermal bridging and other heat loss areas with an Inframetrics Model 525 thermographic camera. To provide consistant results, houses were scanned while under a depressurization of 30 pascals. While in the houses, a permanent record of significant leakage areas was made by taking black and white Polaroid pictures of the image produced by the camera.

Some of the typical air leakage areas in the houses were as follows:

- wall penetrations for such purposes as electrical service entries etc.,
- sliding glass doors,
- sliding windows,
- fresh air inlets of fireplaces, and
- floor header areas.

During retesting in February 1986, work was carried out with an Inframetrics Model 522 colour camera. This testing was done with houses operating under normal pressure conditions. The thermographic scans were used to spot significant areas of thermal bridging, condensation problems,

and air leakage areas. Typical thermograpic scan results are presented and discussed in Appendix B to provide comparisons of detailing from one house to the next. Polaroid pictures of typical air leakage areas are too numerous to include in this report but a few pictures are included for illustrative purposes.

2.3 Backdraft Testing

The standard R-2000 test for backdrafting of combustion appliances (R-2000 Guidelines and Procedures Manual Section 11) was applied to the houses with combustion appliances. Table 2.3.1 provides a summary of the backdraft test results.

Some of the houses in the sample were capable of producing conditions which would backdraft combustion appliances under two conditions. In all cases, it was the fireplaces which tended to backdraft under the conditions of the test. Remedial measures, which may be appropriate to the safe operation of a fireplace, would include increasing the supply air to the combustion chamber and sealing the combustion chamber from the household air.

It should be noted that failing the R-2000 backdraft test does not necessarily mean a house is likely to suffer a backdraft incident. The test basically measures air flow direction (i.e., up or down) in a cold chimney flue. Fireplaces lack an induced draft fan which is considered mandatory on other combustion devices such as gas-fired furnaces and domestic hot water heaters. For this reason, fireplaces have very frequently failed the R-2000 backdraft test. The high number of houses failing the backdraft test has forced a reconsideration of how testing should be performed.

2.4 Sound Level Testing

For sound level testing, two integrating A-weighted (B&K Model 2225) sound level meters were used. A technician operated one meter, 2.5 metres from an outside wall at the front of the houses, while another technician measured sound levels within the house. In some cases, household activities interfered with the testing, therefore, notes are included with these results. 60 second equivalent average noise levels were taken. The results are presented in Table 2.4.1.

TABLE 2.3.1 BACKDRAFT TEST RESULTS

House No.	Backdraft Under Test Conditions	What Backdrafted	Conditions of Backdraft
SUDBURY			
House A			
House B			
House C			
House D			
House E	yes	Fireplace	HRV on high & gas furnace on
KINGSTON			
House A			
House B			
House C			
House D			
House E			
FONTHILL			
House A	yes	Floor drain	Smoke pencil showed air coming up
House B	yes	Fireplace	With HRV on high & gas furnace on
House C			
House D	yes	Fireplace	With HRV on high & furnace & clothes dryer on
House E			
ERIN MILLS			
House A	yes	1st floor Fireplace	Backdrafted when HRV & dryer were on
House B	yes	1st floor Fireplace	With HRV on any speed & F/A furnace on
House C	yes	1st floor Fireplace	HRV on high, furnace on & clothes dryer on
House D			
House E			
House F			
House G			

TABLE 2.4.1 SOUND LEVEL MEASUREMENTS IN THE R-2000 HOUSES WITH FURNACE FAN AND HRV ON HIGH SPEED vs LOW SPEED

	Manufacturer of HRV Unit	Sound levels - 60 sec. LEQ's (dBA) High Speed		Low Speed	
		Inside	Outside	Inside	Outside
SUDBURY					
House A	Air Changer DR150	46	52	48	51
House B	Nutone AE200	45	45		
House C	Nutone AE200	57	48	45	48
House D	Air Changer DR150	41	44	38	54
House E	Air Changer DR150	45	68		
House F *		44	37	37	37
KINGSTON					
House A	Air Changer DR150	47	45	41	46
House B	Air Changer DR150	36	41	27	42
House C	Air Changer DR150	34	41	35	41
House D	Air Changer DR150	49	58	35	52
House E	Air Changer DR275	42	37		
FONTHILL					
House A	Air Changer DR275	38	54	23	54
House B	Air Changer DR150	40	43	39	43
House C	Air Changer DR150	47	54	44	54
House D	P.M. Wright WR25				
House E	Air Changer DR150	39	42	41	45
ERIN MILLS					
House A	Lifebreath 250	40	47	35	47
House B	Lifebreath 250	42	51	33	51
House C	Lifebreath 250	45	51	46	54
House D	Lifebreath 250	43	57	36	57
House E	Lifebreath 250	39	62	38	62
House F	Lifebreath 250				
House G	Lifebreath 250	41		42	

Notes:
* control house

As can be seen from the results, a five to ten dBA difference was observed between the conditions where the HRV was the only mechanical device operating within the home and the conditions where the HRV was on high and the furnace fan was on high. In one particular house, House D in Kingston, a 14 dBA difference was noted. The noise level from the furnace in this household appears to be particularly noticeable.

Generally, when moderate noise levels were present at the exterior of the building (e.g. 50-60 dBA) a 10-20 dBA difference was noted between the interior and exterior sound levels. In view of the fact that very few control houses have been sampled thus far for noise levels as part of this study, it is difficult to compare noise levels in R-2000 houses to noise levels in conventional houses.

2.5 Ventilation Capacity Testing

The ventilation capacity of the equipment in the houses was estimated by taking flow measurements in both air streams of the heat recovery ventilators. Table 2.5.1 indicates the ventilation capacity of the houses. The flows were measured using a C.E.S. flow pressure averaging element linked to a Dwyer Model 115 incline manometer.

As can be seen in the table, many of the tested houses lacked the required capacity to exhaust air at 0.45 air changes per hour (ACH). There appears to be a difference between the older and newer houses in the sample. The newer houses (i.e., the Erin Mills houses) appear to have adequate capacity to exchange air at 0.5 ACH. The older houses generally have difficulty meeting the old 0.45 ACH R-2000 ventilation specification. It appears that retrofitting the ventilation systems in the older houses will be necessary for the systems to meet the R-2000 standards in effect at the time.

During the course of the monitoring program, major ventilation system changes have taken place at four locations. These are listed as upgraded systems in Table 2.5.1. In the Kingston and Fonthill locations, Air Changer DR-150 units were originally installed. In Erin Mills, Lifebreath 250 units were originally installed. The changes in Kingston and Fonthill were undertaken to upgrade seriously undersized units. The changes in Erin Mills were undertaken to evaluate the performance of the new units.

The flows listed in Table 2.5.1 reflect flow data taken after the changes were made.

TABLE 2.5.1 HOUSE VENTILATION SYSTEM CHARACTERISTICS

	Manufacturer of HRV Unit	House Volume (cu.m.)	.5ACH Flow (L/s)	.45ACH Flow (L/s)	Measured Flow Supply (L/s)	Measured Flow Exhaust (L/s)
SUDBURY						
House A	Air Changer DR150	495	69	62	41	47
House B	Nutone AE200	450	63	56	48	47
House C	Nutone AE200	492	68	62	67	56.5
House D	Air Changer DR150	485	67	61	46	46
House E	Air Changer DR150	494	69	67	51	51
KINGSTON						
House A	Air Changer DR150	682	95	85	67	63
House B	Air Changer DR150	621	86	78	42	58
House C	Air Changer DR150	647	90	81	55	43
House D	Air Changer DR150	521	72	65	47	45
House E	Air Changer DR275*	682	95	85	87.5	79
FONTHILL						
House A	Air Changer DR275*	696	97	87	100	85.5
House B	Air Changer DR150	518	72	65	47	47
House C	Air Changer DR150	580	81	73	45	48
House D	P.M. Wright WR25	679	94	85	63	68
House E	Air Changer DR150	573	80	72	45	32
ERIN MILLS						
House A	Lifebreath 250	522	73	65	60.5	70
House B	Lifebreath 250	527	73	66	46	63
House C	Lifebreath 250	527	73	66	61.5	62.5
House D	Lifebreath 250	522	73	65	61.5	66
House E	Van EE 2000	574	79	71	82	76
House F	Air Changer DR275	479	67	60	75	78
House G	Lifebreath 250	479	67	60	84	67

Notes:

* Ventilation system upgraded.

As a general rule, ventilation capacity problems stem from three sources:

- the size of the HRV unit,
- the length of ducting and attention to minimizing flow restrictions such as elbows, and
- the location of the HRV inlet.

Undersized HRV units, excessive ducting and poorly located HRV inlets are reasonably common in the houses being monitored. These problems have, however, been addressed through the subsequent issuing of detailed ventilation system installation guidelines and the certification of ventilation system installers.

2.6 Combustion Appliance Efficiency Testing

The steady state combustion efficiency tests were carried out using a Neotronics Fuel Efficiency Monitor on all but one of the combustion space heating appliances installed in the houses being monitored. The results of tests are shown in Table 2.6.1 along with the make and model of each appliance. At House E in Kingston the exhaust piping of the Lennox Pulse unit did not lend itself to combustion efficiency measurement.

The steady state furnace efficiencies range from 67 percent for a standard non-induced draft unit to 86 percent for a sealed combustion condensing unit.

2.7 Construction Reliability

Throughout the course of the monitoring program, inspections were carried out and the homeowners questionned to determine the extent of any construction-related problems. From this standpoint, the houses have performed extremely well. There has been no evidence of moisture accumulation, including mildew, mold or water staining around windows.

The structural integrity of the basements appears to be very good with none of the houses experiencing water leakage or significant cracking. One house, House B in Fonthill, has had a serious basement water entry problem. This problem occurs at the window wells. The problem is largely one of exterior grading and a dispute exists between the homeowner and the builder as to who is responsible for the grading problem.

TABLE 2.6.1 COMBUSTION EFFICIENCY TESTS

Address	Furnace Type	Furnace Make	Efficiency
SUDBURY			
House A	Electric	Baseboard	-
House B	Natural Gas	Olsen Minimax	69%*
House C	Natural Gas	Olsen Minimax	71%*
House D	Natural Gas	Olsen Minimax	67%*
House E	Natural Gas	Olsen Duamatic Ultramax	86%
KINGSTON			
House A	Electric	Summeraire	-
House B	Electric	Lennox	-
House C	Electric	Lennox	-
House D	Electric	Luxaire (Borg Warner)	-
House E	Natural Gas	Lennox Pulse	Unable to do
FONTHILL			
House A	Natural Gas	York	83%
House B	Natural Gas	York	85%
House C	Electric	Clare	-
House D	Electric	Clare	-
House E	Electric	York	-
ERIN MILLS			
House A	Electric	Clare	-
House B	Electric	Clare	-
House C	Electric	Clare	-
House D	Electric	Clare	-
House E	Electric	Clare	-
House F	Electric	Clare	-
House G	Electric	Clare	-

* It was very difficult to get an accurate determination of efficiency on these units because the dilution air port on the furnace was in close proximity to the burner.

3.0 ENERGY MONITORING

The major purpose of the energy monitoring portion of the program is to quantify the energy use in each house and to compare these actual monitored results with the computer predictions. The computer simulation program HOTCAN is used in the R-2000 program. This computer simulation program was originally developed through the National Research Council of Canada. The program, using building parametric inputs including areas, thermal resistance values, and orientations as well as average climatic data for the location, computes an annual summary of estimated energy consumption. Because the actual data available for this report covers the period from September 1985 to June 1986, some extrapolations were necessary to do direct comparisons with the annual HOTCAN predictions.

Energy monitoring was achieved by installing submeters to segregate the energy used for space heating and the energy used for domestic hot water heating from the total energy used. The meter readings are obtained on a monthly basis during the regular site visit from the submeters and the total energy meters supplied by the local gas and electric utilities for energy billing purposes. Readings of water usage for hot water purposes are also obtained.

3.1 Meter Installation

Buchan, Lawton, Parent Ltd. used the original builders' subtrades to install submeters wherever possible. This approach has two primary benefits; homeowners have a consistent tradesperson to contact in the event of problems, such as a leak at a water meter, and this person is familiar not only with local codes and bylaws but has an intimate familiarity with the layout of services at the site. The major problem encountered with this approach has been the fact that it has been difficult to get some of the tradespeople to complete the installation work in a timely fashion. Table 3.1.1 lists the meters required for this project.

Electrical submetering is done using standard digital reading kilowatt hour meters. Gas submetering is done with standard positive displacement utility-type gas meters. The metering of hot water use is done with positive displacement digital reading meters located on the cold water feed line to the domestic hot water tank.

TABLE 3.1.1 METER REQUIREMENTS

	Water Meters	kWh Meters	Gas Meters
SUDBURY			
House A	1	2	0
House B	1	1	0
House C	1	0	1
House D	1	1	0
House E	1	1	0
KINGSTON			
House A	1	2	0
House B	1	2	0
House C	1	0	0
House D	1	0	0
House E	1	1	0
FONTHILL			
House A	1	1	1
House B	1	1	0
House C	1	2	0
House D	1	3	0
House E	1	2	0
ERIN MILLS			
House A	1	2	0
House B	1	2	0
House C	1	2	0
House D	1	3	0
House E	1	2	0
House F	1	2	0
House G	1	2	0

3.2 Total Energy Use

Total energy use varied signifcantly from the HOTCAN predicted quantities. The comparison of HOTCAN predicted consumptions and actual consumptions extrapolated to a full year are presented in Table 3.2.1.

For the purposes of the necessary extrapolations, the ratio of actual space heating requirements to the HOTCAN predicted requirements is assumed to be a constant ratio. The other energy use, including domestic hot water heating, is assumed to be a constant value on a daily basis.

3.3 Space Heating

In the evaluation of the energy performance of the R-2000 houses being monitored, space heating is the most important quantity to examine. Space heating requirements, although affected by occupant lifestyles, are far less affected than other energy quantities. The major external factor affecting the space heating requirements is the actual weather conditions. Appendix C contains the degree day data for the monitoring period along with the average degree day data used by HOTCAN for each community.

The comparison of the HOTCAN predictions of annual space heating energy consumption with the annual extrapolated monitored quantities are presented in Table 3.3.1.

The monitoring results indicate that the average house used forty five percent more energy than predicted by HOTCAN for space heating. The Sudbury houses showed the closest correlation with predicted energy use with the average actual use being eight percent above predicted.

The individual plots of the actual monthly energy use and the predicted HOTCAN use are included with the house profiles presented in Appendix A.

A typical HOTCAN output is included as Appendix D.

Some factors contributing to the higher than expected space heating requirements in the Erin Mills houses include improperly adjusted thermostat anticipators and air distribution problems. Cold areas, particularly in the bathrooms, may have contributed to the occupants setting thermostats at higher than normal settings to compensate for the cold bathrooms.

TABLE 3.2.1 TOTAL ANNUAL ENERGY CONSUMPTION*

	ACTUAL** (kWh)	ACTUAL/ HOTCAN
SUDBURY		
House A	20731	1.25
House B	24538	1.36
House C	21319	1.14
House D	26119	1.37
House E	24485	1.22
KINGSTON		
House A	25517	1.34
House B	28332	1.54
House C	24522	1.27
House D	18025	1.05
House E	24368	1.21
FONTHILL		
House A	23995	1.31
House B	24440	1.43
House C	25170	1.47
House D	24170	1.30
House E	23672	1.37
ERIN MILLS		
House A	18163	1.06
House B	29562	1.65
House C	22749	1.31
House D	20701	1.15
House E	34612	1.65
House F	19540	1.21
House G	19104	1.24

Notes:

* Includes space heating, domestic hot water heating and all electrical energy.

** Actual energy consumption has been extrapolated to a full year's data from eight months of monitored data.

TABLE 3.3.1 SPACE HEATING ENERGY CONSUMPTION

	ACTUAL* (kWh)	ACTUAL/ HOTCAN
SUDBURY		
House A	11200	1.27
House B	6698	0.85
House C	11163	1.32
House D	9137	1.03
House E	8936	0.91
KINGSTON		
House A	13472	1.52
House B	11562	1.42
House C	10521	1.17
House D	10907	1.57
House E	8748	0.88
FONTHILL		
House A	11024	1.35
House B	12617	1.83
House C	8387	1.22
House D	12868	1.54
House E	11739	1.67
ERIN MILLS		
House A	14291	2.07
House B	17430	2.27
House C	13027	1.83
House D	13210	1.69
House E	17217	1.60
House F	7950	1.34
House G	9401	1.82

Notes:

* Actual energy consumption has been extrapolated to a full year's data from eight months of monitored data.

The thermostat anticipator problems were corrected in all Erin Mills houses. The bathroom air distribution problem is yet to be addressed.

3.4 Domestic Hot Water Heating

Domestic hot water use for each house is shown in Table 3.4.1. A linear extrapolation has been done to show use on an annual basis. HOTCAN uses a standard consumption of 14 kWh per day.

The average house consumed 13.93 kWh per day of hot water which was within one percent of the HOTCAN predicted value. For the individual houses, the domestic hot water usage ranged from forty percent above the HOTCAN assumed value to fifty seven percent below the assumed value.

TABLE 3.4.1 ANNUAL DOMESTIC HOT WATER CONSUMPTION*

	FLOW (m^3)	ENERGY (kWh)
SUDBURY		
House A	93	5227
House B	107	6066
House C	56	3581
House D	97	5307
House E	75	5767
KINGSTON		
House A	65	4406
House B	106	8224
House C	72	5825
House D	26	2205
House E	55	4373
FONTHILL		
House A	89	5406
House B	80	4471
House C	85	5815
House D	57	4939
House E	--	4566
ERIN MILLS		
House A	50	3873
House B	104	7165
House C	60	4201
House D	62	3982
House E	113	7439
House F	66	5238
House G	48	3822

Notes:

* Actual flow and energy consumption have been extrapolated to a full year's data from eight months of monitored data.

4.0 AIR QUALITY ANALYSIS

The air quality analysis undertaken for this study has centered on the measurement of four potential pollutants. These include:

- formaldehyde,
- radon,
- carbon dioxide, and
- carbon monoxide.

Formaldehyde, carbon dioxide and carbon monoxide are measured using difussion-type samplers which are deployed in each house during the monthly site visit and returned one week later by the homeowner to Buchan, Lawton, Parent Ltd. using supplied preaddressed courier envelopes. Radon sampling is done on a three-month rotation with the samplers deployed during one site visit and removed during the site visit three months later.

Throughout the program, formaldehyde sampling has been done with Air Quality Research Incorporated diffusion PF1 sampler tubes. Radon sampling has been carried out using Terradex sample cups. Carbon monoxide and carbon dioxide sampling has been carried out using Drager diffusion tubes.

The Drager diffusion tubes used for carbon monoxide and carbon dioxide sampling were originally designed for eight hour exposures at relatively high pollutant concentrations. Buchan, Lawton, Parent Ltd. has been using these tubes for seven day exposures at the relatively low pollutant concentrations expected in indoor residential environments. A major chamber calibration study is underway to completely characterize these devices under the seven day exposure conditions. The progress on the Chamber Study is discussed in detail in Appendix E.

4.1 Formaldehyde Sampling

Formaldehyde sampling is taken in two locations in each of the houses. One location is in the area of the dining room, the second location is in a bedroom. As a general rule, no significant difference in any individual house is found between readings in the bedroom and the dining room.

A review of the data shows several significant trends. Approximately one percent of all samples taken exceed the currently accepted long-term exposure limit of 0.1 parts per million of formaldehyde. Approximately

forty percent of all samples taken exceed the new proposed limit on long-term exposure to formaldehyde of 0.05 parts per million.

As a general rule, where there has been a variation in formaldehyde readings in an individual house over the monitoring period, the trend has been for a decrease in formaldehyde levels. This is consistent with the aging of building materials. One notable exception is House A in Fonthill where formaldehyde levels were stable at approximately 0.04 parts per million until the homeowner elected to operate the HRV on an intermittent basis, at which time formaldehyde levels doubled. Insufficient data is available to substantiate this trend at this or other locations where homeowners have elected to manually control their HRV units.

4.2 Radon Sampling

Each house in the monitoring program has been sampled for radon in two basement locations. The sampling results have indicated an average radon concentration of less than two picocuries per litre. The currently accepted long-term exposure limit for radon is four picocuries per litre. Only one individual reading was in excess of the four picocuries per litre guideline. This reading was 5.2 picocuries per litre. The companion sampler in this house at the same time read 3.9 picocuries per litre. Due to homeowner error, no other samplers have been available from this location. The new proposed long-term exposure limit to radon from Health and Welfare Canada is 20 picocuries per litre.

4.3 Carbon Dioxide Sampling

Carbon dioxide diffusion tube samplers were located in two locations in each house on a monthly basis. The readings between the two samplers, in almost all cases, were very consistent.

The average readings for the individual houses range from approximately 500 parts per million to 800 parts per million. Table 4.3.1 shows the average carbon dioxide concentrations for each location. Figure 4.3.1 illustrates the average monthly carbon dioxide concentrations for all houses over the period from September 1985 to April 1986.

As is shown in Figure 4.3.1, throughout the period for which results are available, it appears that the carbon dioxide concentrations peak during

TABLE 4.3.1 AVERAGE CARBON DIOXIDE CONCENTRATIONS

	Carbon Dioxide Concentration ppm
SUDBURY	
House A	618
House B	648
House C	664
House D	767
House E	614
KINGSTON	
House A	526
House B	530
House C	561
House D	614
House E	719
FONTHILL	
House A	508
House B	464
House C	624
House D	648
House E	554
ERIN MILLS	
House A	541
House B	512
House C	584
House D	533
House E	578
House F	510
House G	516

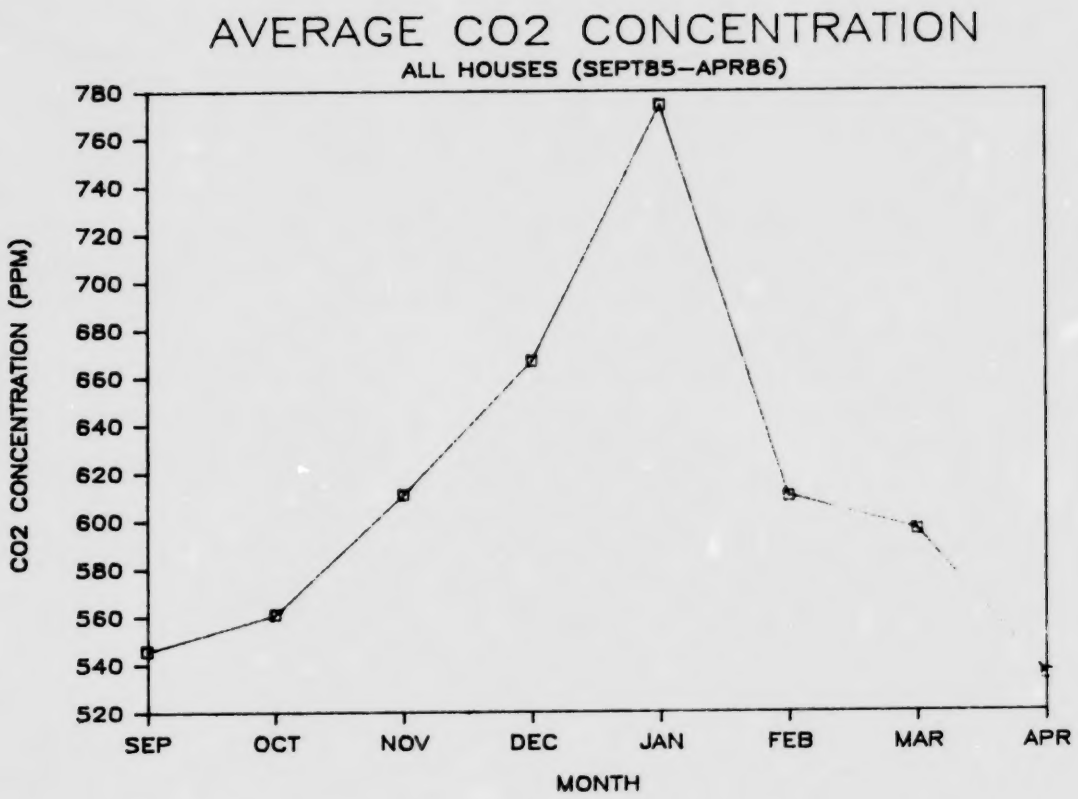

AVERAGE CO2 CONCENTRATION
ALL HOUSES (SEPT85–APR86)
CO2 CONCENTRATION (PPM)
780
760
740
720
700
680
660
640
620
600
580
560
540
520
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 4.3.1

the colder portion of the year with the highest readings generally found in the January/February period.

All readings were below both the proposed Health and Welfare Canada standard of 3500 parts per million and the ASHRAE recommended exposure level of 1500 parts per million.

4.4 Carbon Monoxide Sampling

Carbon monoxide samplers were deployed in two locations in each house. The locations, such as near fireplaces and combustion furnaces, were selected to reflect combustion sources. Data was not available from the carbon monoxide sensors for the early portion of the program due to defective Drager tube samplers. The Drager company recalled all of the samplers which were used in the early portion of the program due to a manufacturing fault. For this reason, sample data has only been collected since the February sampling period.

The chamber study results for the calibration of the carbon monoxide sensors are not yet available. However, the uncorrected carbon monoxide readings for all locations indicate that the carbon monoxide levels range from zero to a fraction of one part per million. This would indicate that the carbon monoxide levels are well within the long-term exposure guidelines.

5.0 DETAILED MONITORING

5.1 Description of Monitoring Equipment

One house was selected for detailed monitoring in each of the monitored communities.

The detailed monitoring consists of minute-by-minute measurement and the hourly recording of average temperatures and humidities throughout the houses, as well as, the detailed performance monitoring of mechanical systems. Under the program, the emphasis is placed on the operation of the heat recovery ventilator unit.

The basic monitoring system hardware consists of an IBM PC equipped with dual disk drives and a Sciemetrics Model 8082 data scanner.

In each of the houses with monitoring equipment, relative humidities are measured at three locations and temperatures are measured at eight locations. The location of the sensors for temperature and humidity measurement are described in Table 5.1.1. The sensor locations are also shown on the floor plans for the appropriate houses in Appendix A.

In order that enthalpy balances can be made on the heat recovery ventilator equipment, wet bulb/dry bulb and flow measurements are recorded. In addition to these measurements, the status for high speed operation and defrost are also recorded. Figure 5.1.1 shows the schematic layout of the instrumentation for a heat recovery ventilator. Figures 5.1.2 to 5.1.5 illustrate views of the actual instrumentation installations.

5.2 HRV Performance

The following subsections deal with the performance of the heat recovery ventilators (HRVs) as monitored by the data acquisition systems. This is broken down by community. Each site has specific details and history which must be taken into account when evaluating the recorded data. These are noted at the beginning of each subsection.

TABLE 5.1.1 DATA ACQUISITION SYSTEM SENSOR LOCATIONS

Sensor I.D.	Sudbury	Kingston	Fonthill	Erin Mills
R.H. & Temp 1	Hall near Main Bath.	Mast. Bdrm. with Bath.	Hall near Main Bath.	Upstairs Hallway
R.H. & Temp 2	Kitchen	Kitchen	Kitchen	Kitchen
R.H. & Temp 3	Laundry Area	Hall near Laundry Rm.	Hall near Laundry Rm.	Basement
Temp 4	Mast. Bedroom	Living Room	Extra Bedroom	Master Bedroom
Temp 5	Mast. Bdrm. Duct	Living Rm Duct	Bedroom Duct	Master Bdrm. Duct
Temp 6	Second Bedroom	Mast. Bdrm. Duct	Dining Room	Second Bedroom
Temp 7	Living Rm Duct	Second Floor Den	Dining Rm Duct	Living Room
Temp 8	Basmt. Fam. Room	Basement	Basement	Sitting Room

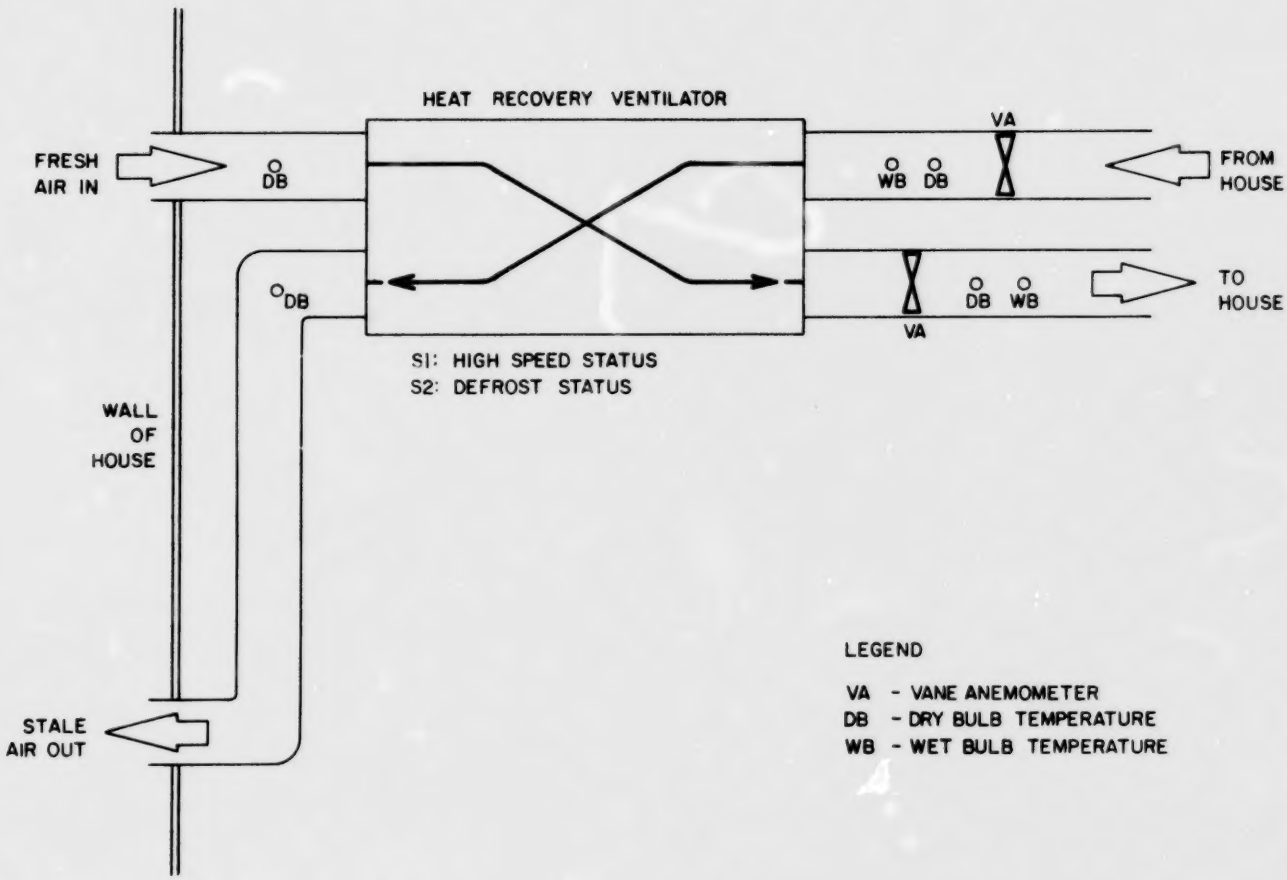


Figure 5·1·1 HEAT RECOVERY VENTILATOR INSTRUMENTATION

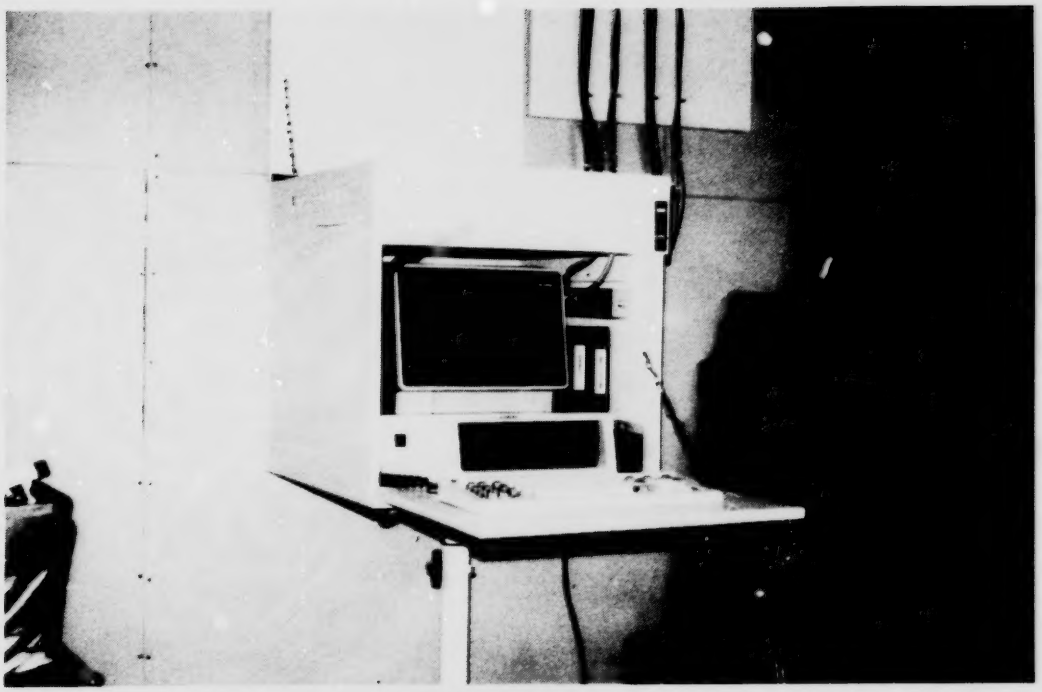


FIGURE 5.1.2
DATA ACQUISITION SYSTEM STORAGE BOX
SHOWING COMPUTER INSTALLATION

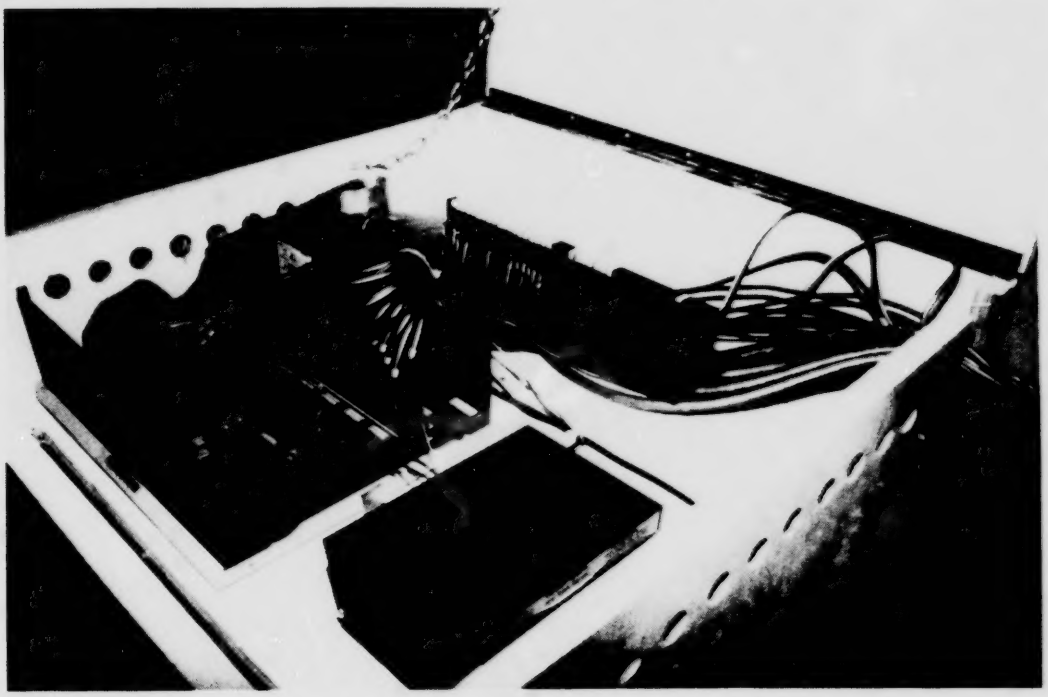


FIGURE 5.1.3
DATA ACQUISITION SYSTEM
STORAGE BOX SHOWING M8082A INSTALLATION

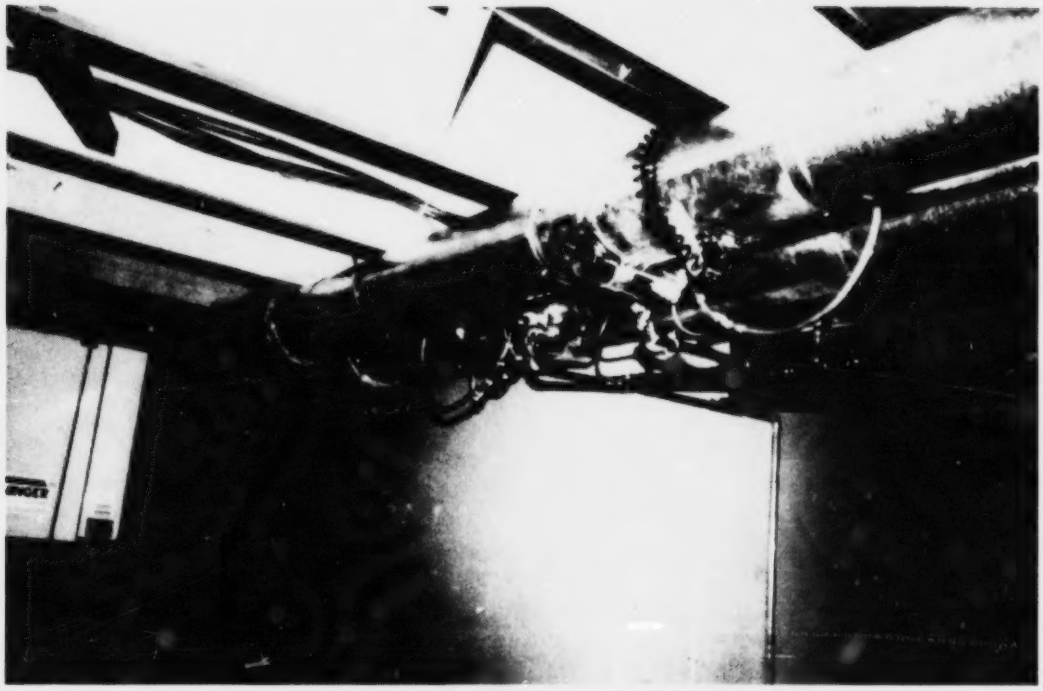


FIGURE 5.1.4
HEAT RECOVERY VENTILATOR WET/DRY
BULB SENSORS

FIGURE 5.1.5
TYPICAL WALL MOUNT HUMIDITY/TEMPERATURE
SENSOR

Energy data is expressed in terms of "heat recovery efficiency":

$$\text{heat recovery efficiency} = \frac{(m_{sup}\,(h_2 - h_1) - Qf)}{(m_{exh}\,h_{3s} - m_{sup}\,h_{1s}) + Qf}$$

where:

m_{sup} = supply mass flow
m_{exh} = exhaust mass flow
h_1 = enthalpy of air at cold supply (sensible and latent)
h_{1s} = enthalpy of air at cold supply (sensible)
h_2 = enthalpy of air at warm supply (sensible and latent)
h_3 = enthalpy of air at warm exhaust (sensible and latent)
h_{3s} = enthalpy of air at warm exhaust (sensible)
Qf = fan dissipation heat factor (dependent on model and fan speed)

HRV model	Speed	Qf (kW)
Air Changer DRP-275	low	0.055
	high	0.14
Lifebreath 250	low	0.03
	high	0.085
Nutone AE500	not available	

5.2.1 Nutone AE-500 in Sudbury

The monitoring in Sudbury began on September 13, 1985. The HRV is a Nutone AE-500 which is a "heat wheel" type heat exchanger. A number of problems were experienced over the winter resulting primarily from an inherent defrost problem with this unit in cold climates. In very cold weather, these units have a history of freezing. This stops the rotation of the heat transfer wheel and often results in the failure of the drive belt. Two periods of HRV performance data were lost due to this problem. When the heat wheel rotation has stopped, the wheel will not necessarily restart on its own.

Figure 5.2.1 shows the daily average supply and exhaust flows. The days indicated as zero flow are periods when daily averages were not available. The average measured supply flow rate is about 47 L/s and the average

supply exhaust balance ratio is 0.81. These figures are somewhat optimistic. The defrost system in this type of unit works on a bypass principle. During defrost the actual ventilation rate of the house is effectively zero. Figure 5.2.2 shows the percentage of time, by day, that the unit was in defrost mode plotted against outdoor temperature. This suggests that, at low ambient temperatures, there would be a dramatic reduction in the actual ventilation efficiency of the unit. The daily average exhaust flow versus the ambient temperature plot as shown in Figure 5.2.3 has been adjusted for defrost flow reduction.

In the energy calculations, the cross flow and fan heat dissipated into the airstream have not been taken into account. The heat recovery efficiency of the unit, on a daily average basis, is shown in Figure 5.2.4.

5.2.2 Air Changer DRP-275 in Kingston

The monitoring in Kingston started on September 16, 1985. At that time, an Air Changer model DRP-150 was in place which provided inadequate air flow for the size of the house. The decision was made to change the end panel of the HRV, upgrading it to the equivalent of a model DRP-275. This was done on November 13, 1985. The defrost status circuit on the HRV did not function until April 25, 1986. This was not significant since the installed backup runtime meter showed that no defrost had occurred. The lack of defrost time was probably due to the relatively high flow volume of warm exhaust air compared to the supply flow volume.

There has been an unusual problem with the data acquisition system used in Kingston. The system reliably recorded the measured data (temperature, humidities, flows, high and low speed status) but stored unreasonable numbers for calculated values such as energy flows. The problem was eventually traced to an incompatibility between the multi-function card containing the real time clock and the data acquisition hardware. The same type of problem had been noticed on a rare, intermittent basis with the other systems. In Kingston, most of the calculated data was unreliable. This problem seems to have been solved by changing the multi-function card to that of another manufacturer.

Due to the aforementioned problems, the heat recovery efficiency calculations presented here are based on hourly averages of measured data for typical winter conditions. An estimate of fan power has been included, but no allowance has been made for cross leakage.

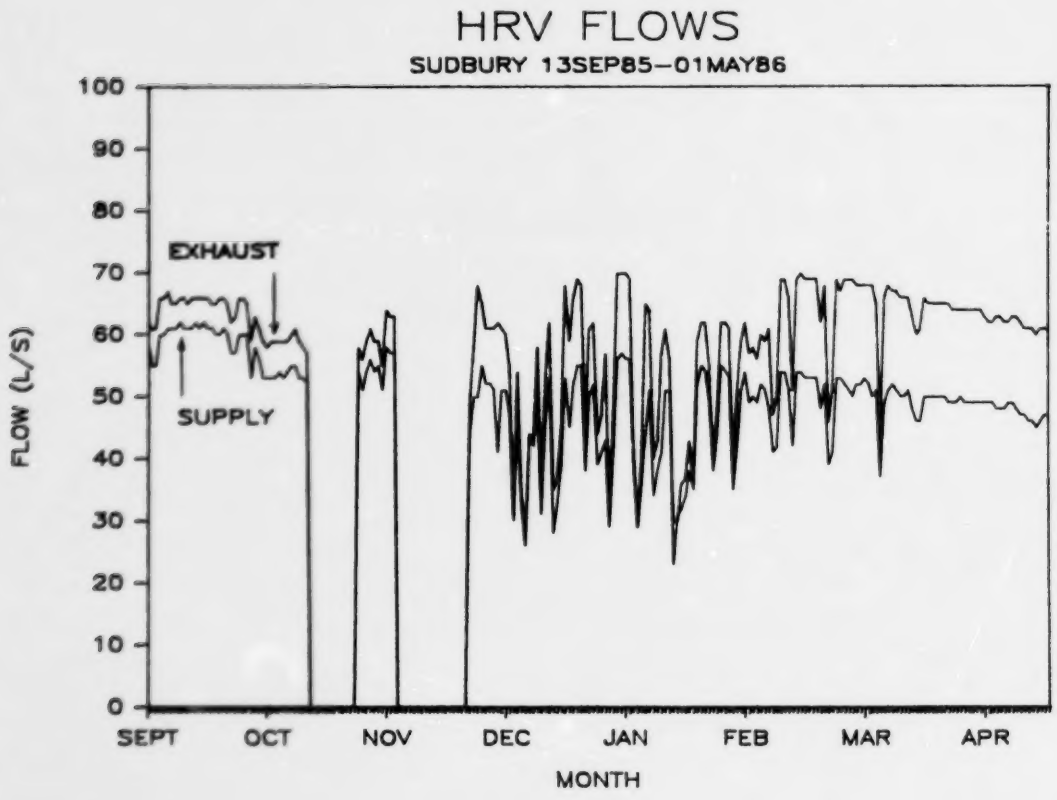

HRV FLOWS
SUDBURY 13SEP85–01MAY86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
EXHAUST
SUPPLY
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 5.2.1

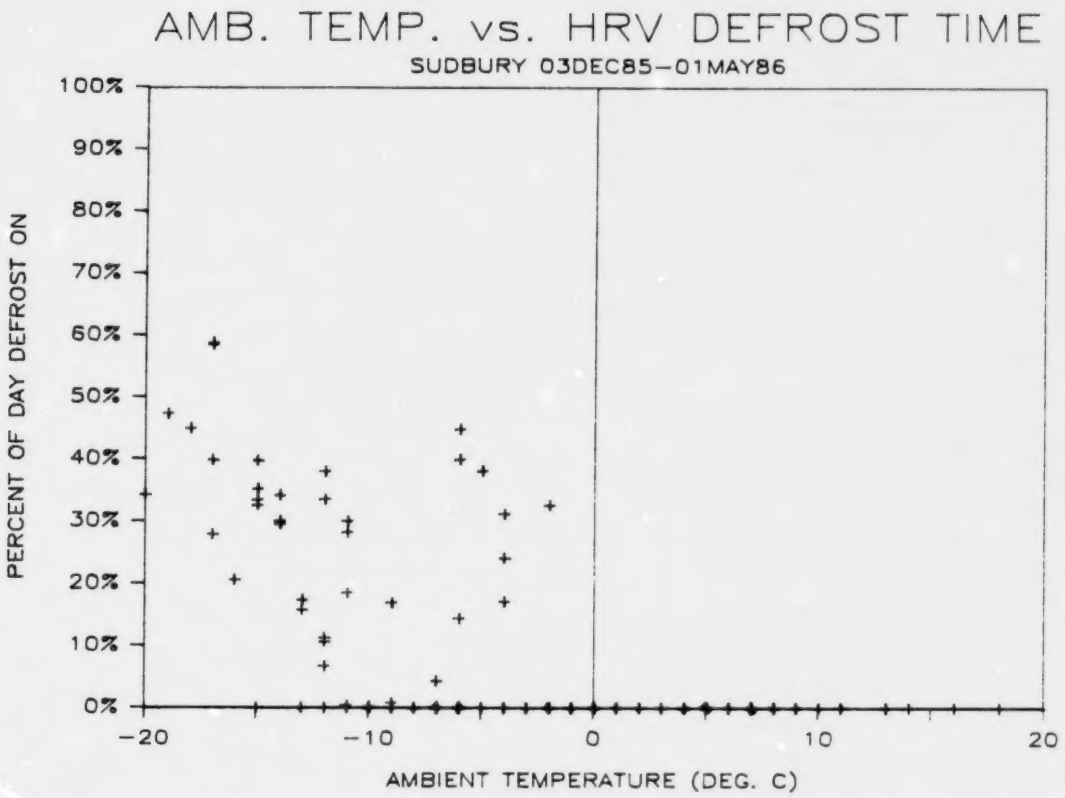

AMB. TEMP. vs. HRV DEFROST TIME
SUDBURY 03DEC85–01MAY86
PERCENT OF DAY DEFROST ON
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
−20
−10
0
10
20
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.2

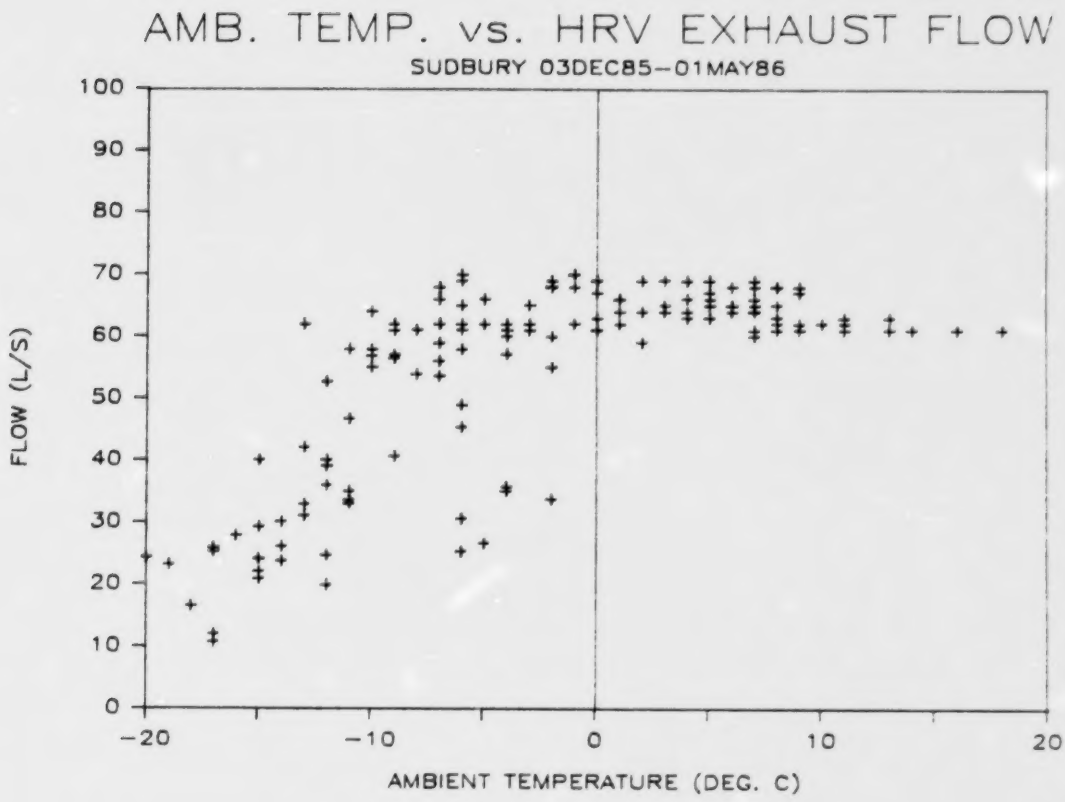

AMB. TEMP. vs. HRV EXHAUST FLOW
SUDBURY 03DEC85–01MAY86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
–20
–10
0
10
20
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.3

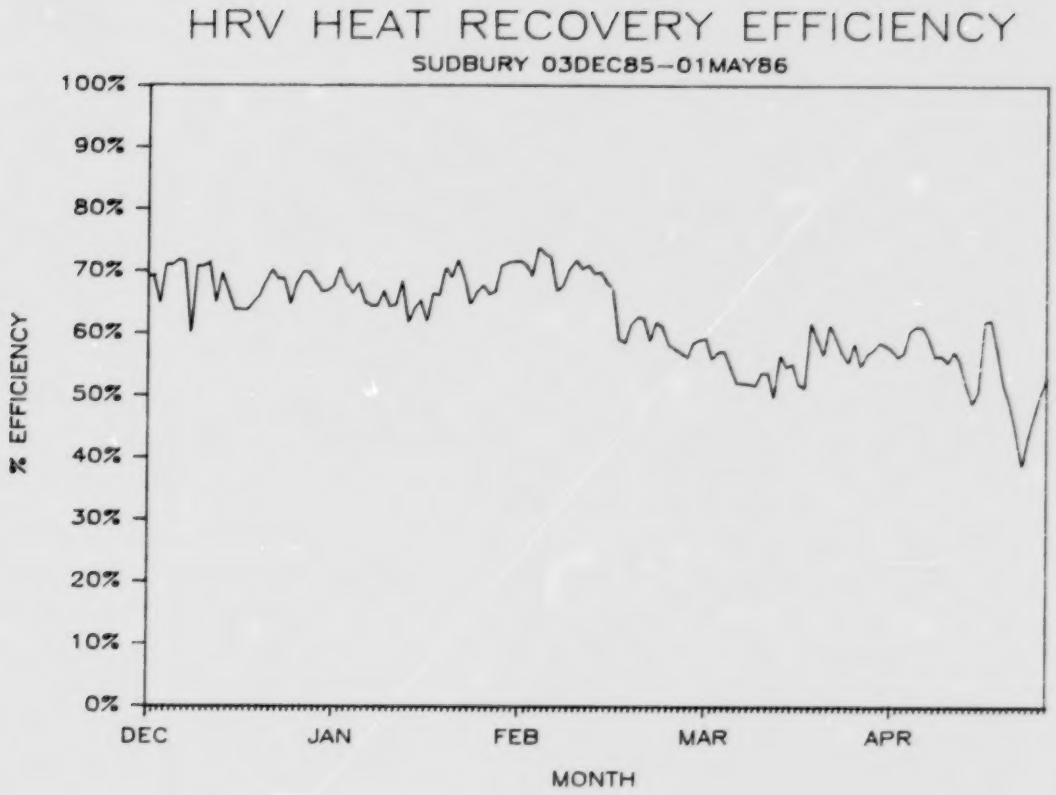

HRV HEAT RECOVERY EFFICIENCY
SUDBURY 03DEC85–01MAY86
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% EFFICIENCY
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 5.2.4

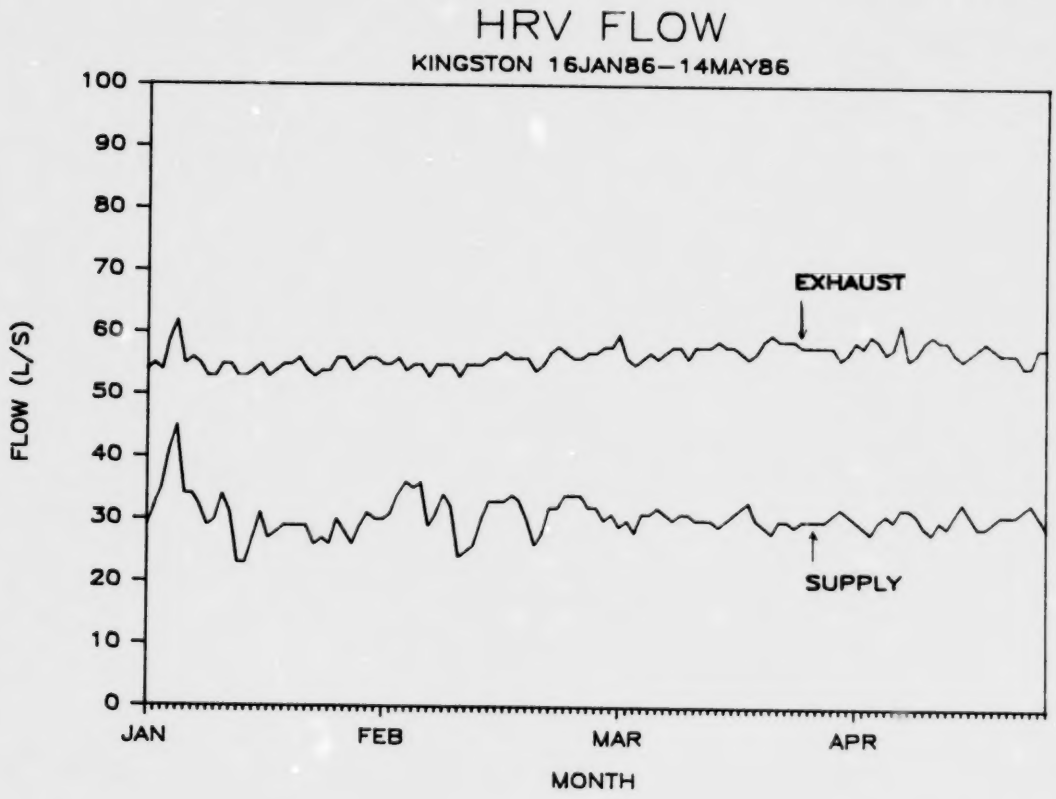

HRV FLOW
KINGSTON 16JAN86–14MAY86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
EXHAUST
SUPPLY
JAN
FEB
MAR
APR
MONTH

FIGURE 5.2.5

The most obvious concern with this DRP-275 is that the flows are not well balanced. This is shown in Figure 5.2.5. No changes were made to the ductwork at the time of the HRV upgrade and in the original installation, there was no installation of balancing dampers.

Some high speed flow was recorded on the unit. On high speed, the supply flows increased from an average of 31 L/s to 63 L/s. On high speed, the imbalance reduced from the average of 0.55 (supply/exhaust) to about 0.8.

The heat recovery efficiency averaged approximately 50 percent, as shown in Figure 5.2.6. Because no defrost was recorded, there was no significant change in HRV exhaust flow rate with temperature. This is shown in Figure 5.2.7. The supply flow rate, similarily, showed no temperature dependent trends.

5.2.3 Air Changer DRP-275 in Fonthill

The monitoring of the HRV initially began on September 25, 1985. At that time the unit in place was an Air Changer model DRP-150. This unit was upgraded to a model DRP-275 on November 15, 1985. The defrost channel was operational as of the 19th of February, 1986. Prior to this, there was only 2.3 hours of defrost time recorded by the runtime meter, and one hour of defrost time after that date.

The energy calculations presented here include an estimate of fan power but make no allowance for cross leakage.

Figure 5.2.8, which shows supply and exhaust flows, demonstrates the flow history of the unit. The days of zero flow are periods when daily averages were not available. In the initial period from September to November, the originally installed DRP-150 was in place. Modification, by the installation of a DRP-275 front panel, increased the supply and exhaust flows. Typically, the supply flow averaged 55 L/s with a supply/exhaust flow ratio of 0.9. The homeowner started to control the HRV after January 15, 1986. After that time the flows were very erratic. Most of the high speed operation (of which there was a significant amount) occurred after that date.

This unit has an unusual characteristic while on high speed. When the unit is turned on to high speed, the supply flow increases much more than the exhaust flow. This is shown in Figure 5.2.9. This characteristic was typical of other DRP-275 units tested. This operational characteristic was

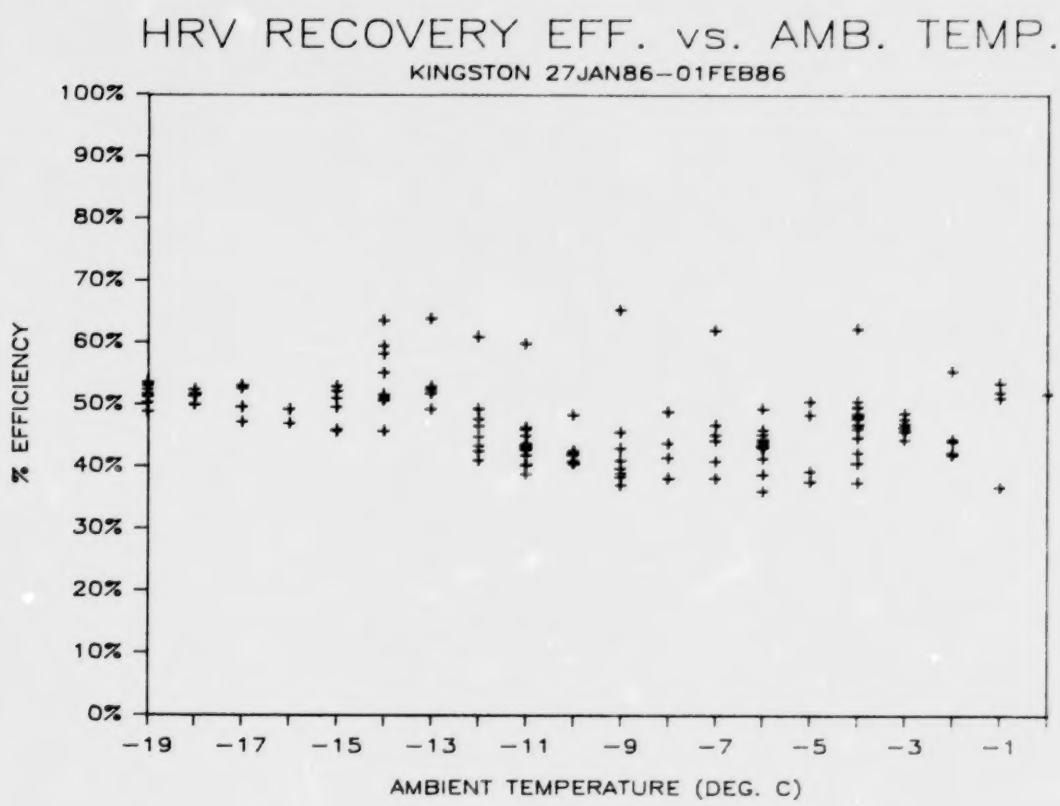

HRV RECOVERY EFF. vs. AMB. TEMP.
KINGSTON 27JAN86–01FEB86
% EFFICIENCY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
–19
–17
–15
–13
–11
–9
–7
–5
–3
–1
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.6

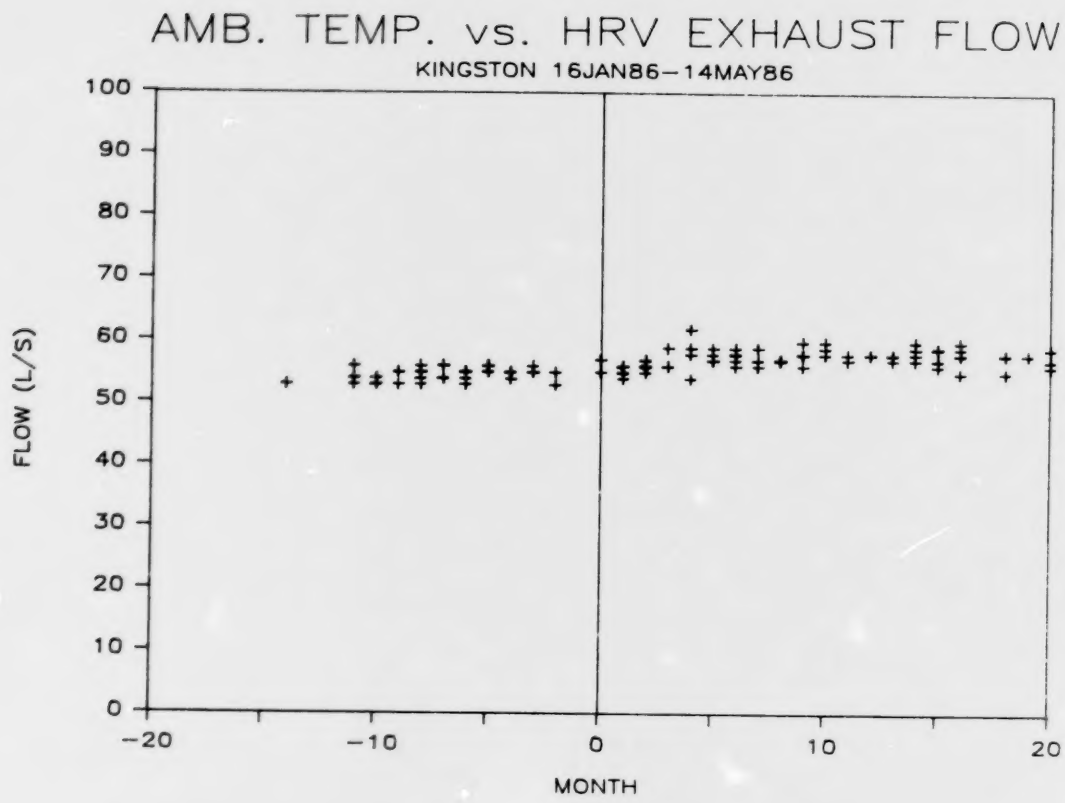

AMB. TEMP. vs. HRV EXHAUST FLOW
KINGSTON 16JAN86–14MAY86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
–20
–10
0
10
20
MONTH

FIGURE 5.2.7

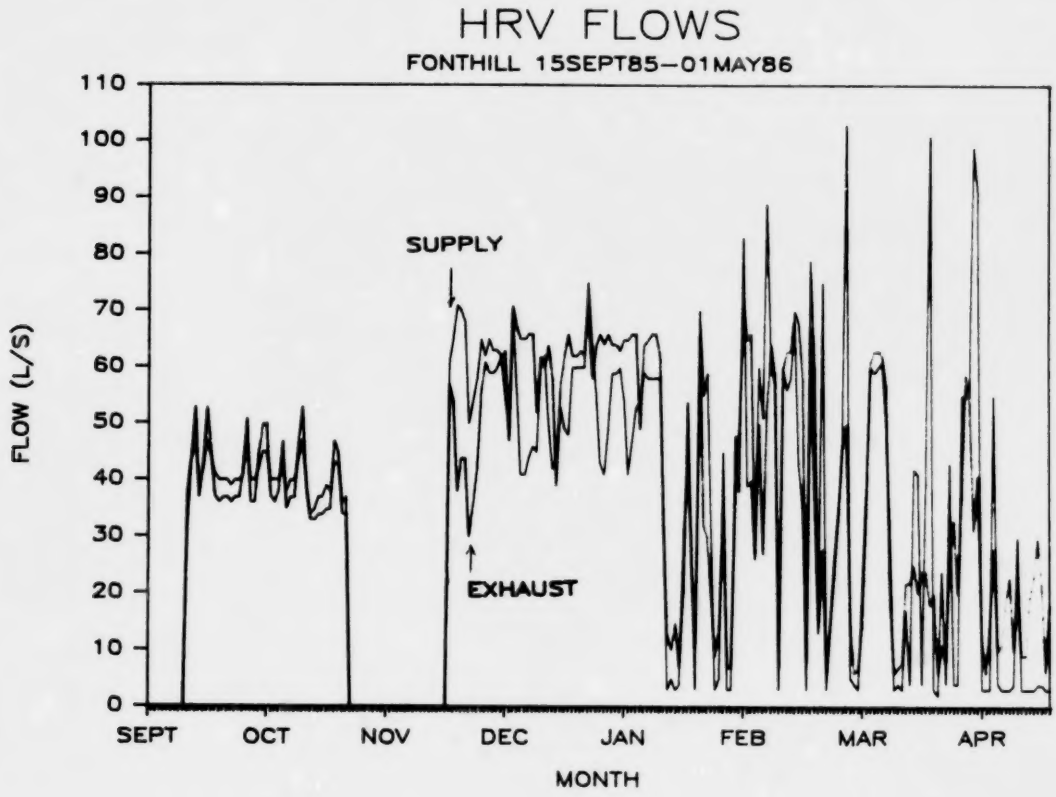

HRV FLOWS
FONTHILL 15SEPT85–01MAY86
FLOW (L/S)
110
100
90
80
70
60
50
40
30
20
10
0
SUPPLY
EXHAUST
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 5.2.8

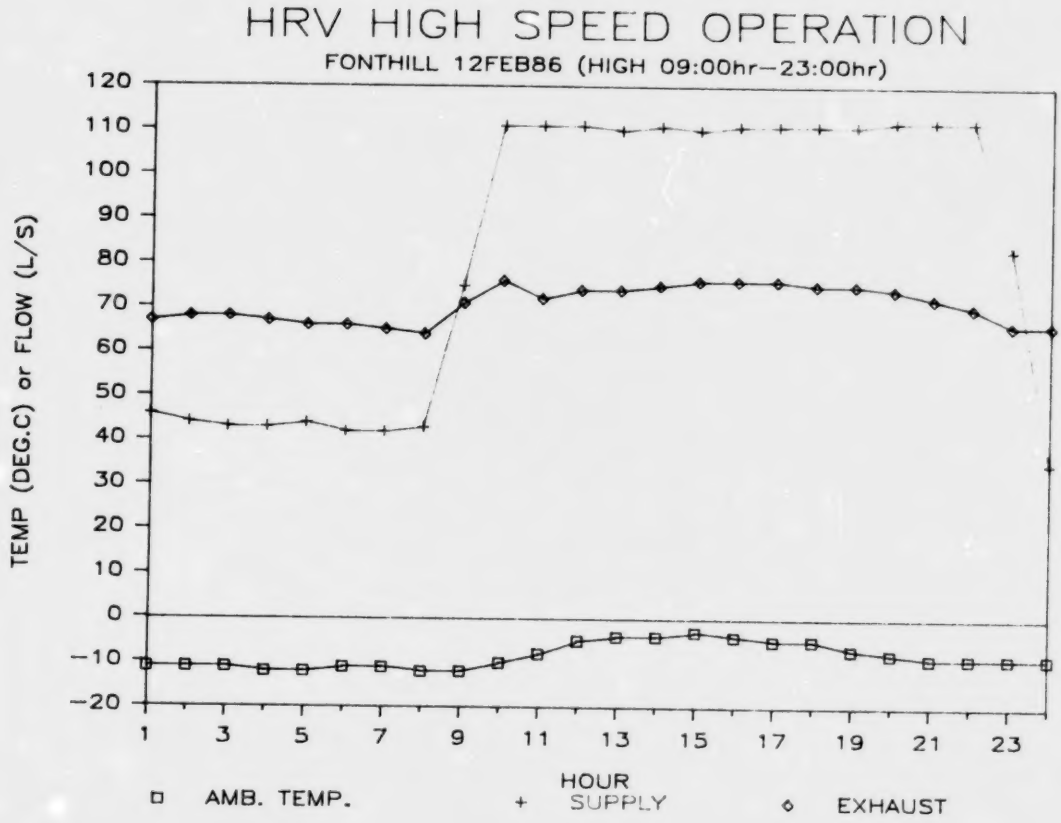

HRV HIGH SPEED OPERATION
FONTHILL 12FEB86 (HIGH 09:00hr–23:00hr)
TEMP (DEG.C) or FLOW (L/S)
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
1
3
5
7
9
11
13
15
17
19
21
23
HOUR
AMB. TEMP.
SUPPLY
EXHAUST

FIGURE 5.2.9

brought to the attention of the Air Changer Company and they claimed this was normal operation for the unit.

Little defrost time has been recorded. Consequently, there is no noticeable trend to the reduction in flow volume as outdoor temperature goes down. This is shown in Figure 5.2.10.

The calculated heat recovery efficiency of this unit, as shown in Figure 5.2.11, has been significantly better than the DRP-275 in Kingston.

Figures 5.2.12 and 5.2.13 have been included to indicate that the HRV was effective in reducing humidity in the house. In both these figures, it can be seen that the relative humidities were relatively stable under normal operation and, when the humidistat switched the HRV on to high speed, the humidities were significantly reduced.

5.2.4 Nutech Lifebreath 250 in Erin Mills

The monitoring of the HRV in Erin Mills began on October 10, 1985. No high speed or defrost operation has been recorded from this unit. The homeowner began to control the HRV on about February 17, 1986. Prior to that date, the data reflected the automatic operations of the HRV. Since that date, the operation of the unit has been controlled by a time clock which is overridden by the homeowner at his discretion.

Figure 5.2.14 shows supply and exhaust flows over the monitoring period. The one section shown as zero flow in this graph is a period when daily average data was not available due to software problems. During automatic operation, the supply and exhaust flows were well balanced at an average level of about 44 L/s. When the homeowner started manually operating the HRV, the flows varied greatly. During this period, an interesting phenomenon appeared. When the HRV was off, the data acquisition system still recorded a significant flow on the exhaust side. When this was checked during a site visit, it was found that there was no significant flow in the duct, indicating some kind of instrument or "noise" problem in a zero flow situation. Calibration checks indicated that the measured flows under an operating condition were reliable. The possible "noise" problem may be attributable to the 60 Hz power supply, since the measured flow corresponded to a near 60 Hz frequency.

During the period of automatic operation, no high speed or defrost operations were recorded. There is a possibility that there may be an

brought to the attention of the Air Changer Company and they claimed this was normal operation for the unit.

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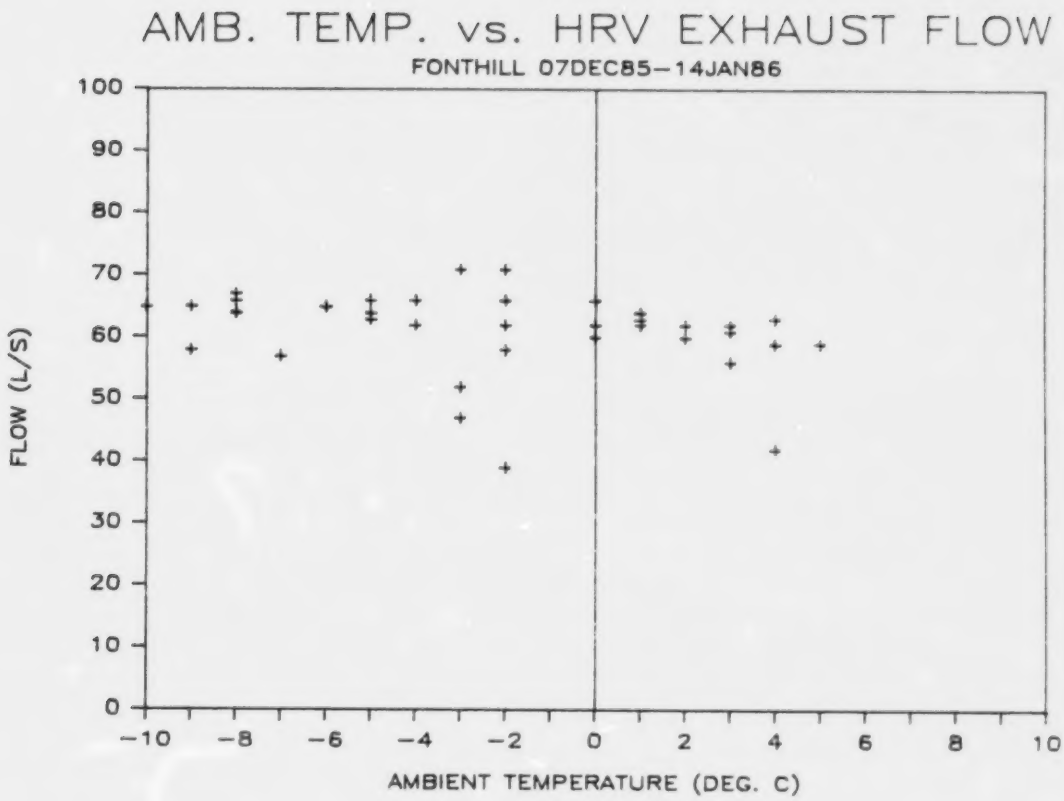

AMB. TEMP. vs. HRV EXHAUST FLOW
FONTHILL 07DEC85–14JAN86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
−10
−8
−6
−4
−2
0
2
4
6
8
10
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.10

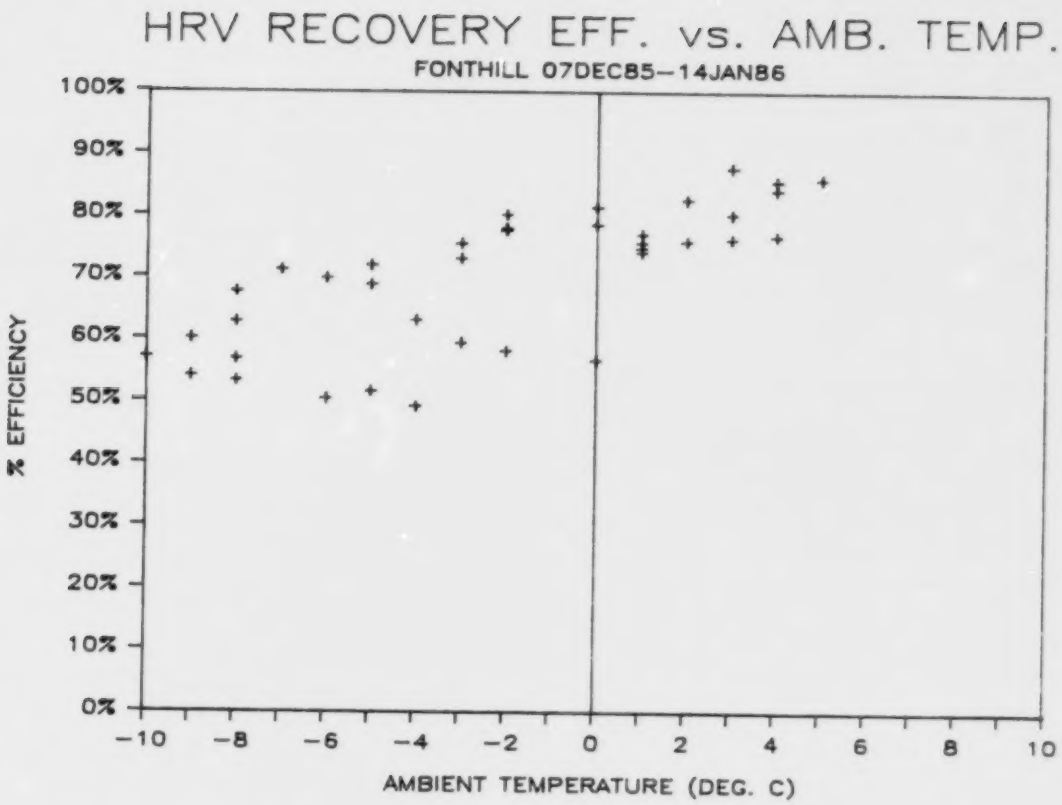

HRV RECOVERY EFF. vs. AMB. TEMP.
FONTHILL 07DEC85–14JAN86
% EFFICIENCY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
−10
−8
−6
−4
−2
0
2
4
6
8
10
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.11

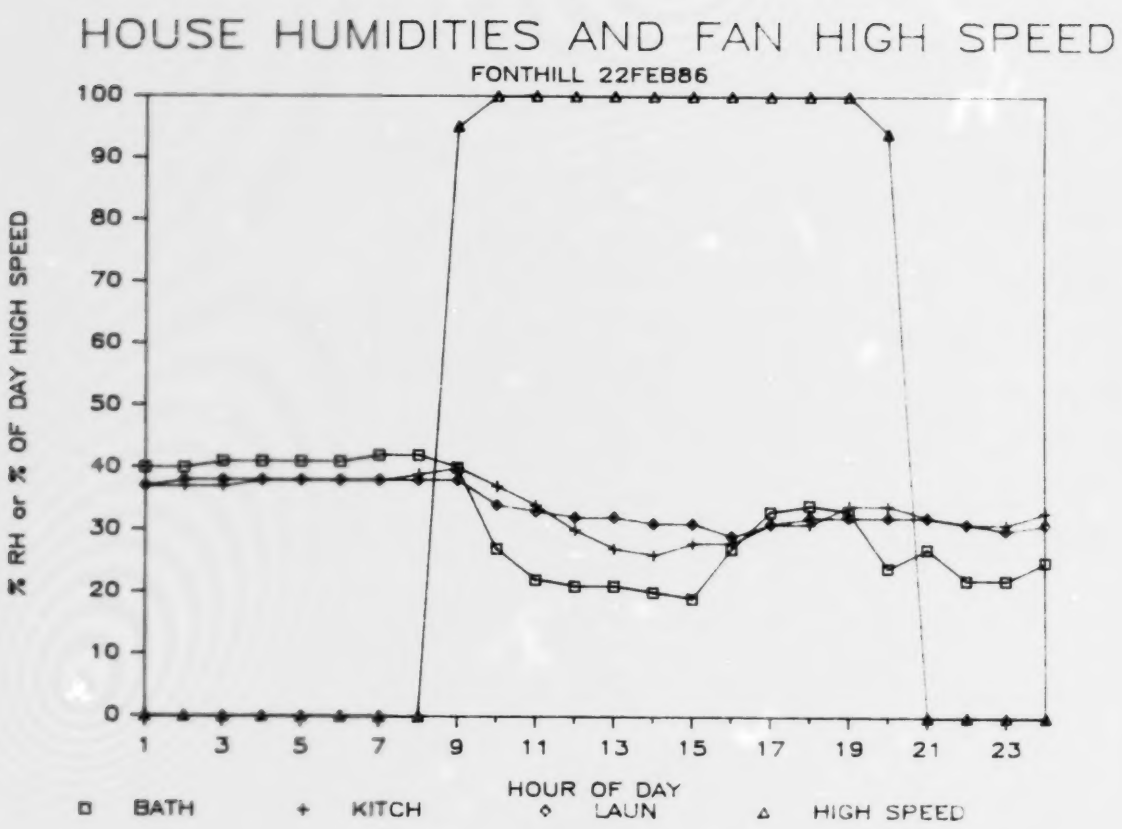

HOUSE HUMIDITIES AND FAN HIGH SPEED
FONTHILL 22FEB86
% RH or % OF DAY HIGH SPEED
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATH
KITCH
LAUN
HIGH SPEED

FIGURE 5.2.12

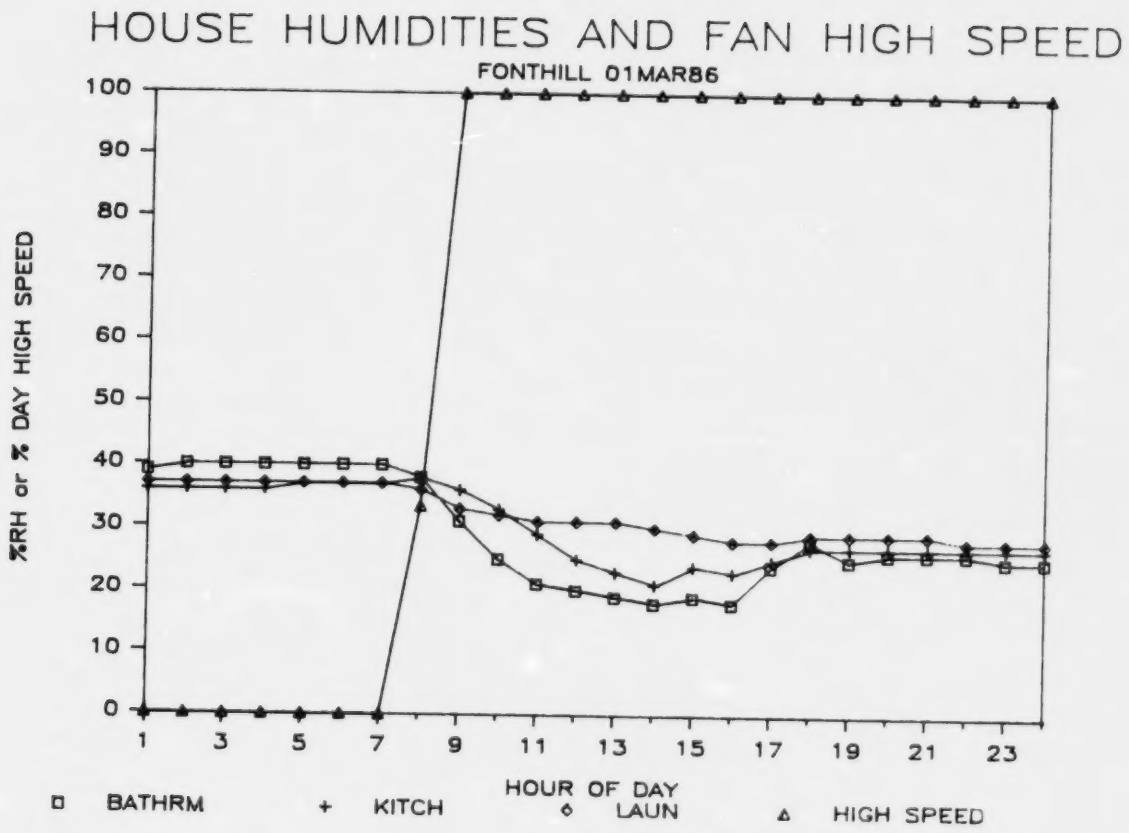

HOUSE HUMIDITIES AND FAN HIGH SPEED
FONTHILL 01MAR86
%RH or % DAY HIGH SPEED
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
HOUR OF DAY
BATHRM
KITCH
LAUN
HIGH SPEED

FIGURE 5.2.13

instrumentation problem in measuring defrost status. A review of the flow data indicated that little, if any, high speed operation occurred.

The exhaust flows have remained relatively constant, as demonstrated when plotted against the ambient temperature as seen in Figure 5.2.15. The supply flows show a similar trend.

The heat recovery efficiency of the unit (not taking into account cross flow but including an allowance for fan power) was relatively good, averaging about 70 percent throughout the operating temperature range. This is shown in Figure 5.2.16.

5.3 Temperature and Humidity Control

As detailed in the section covering the description of the monitoring equipment, each of the four houses with a data acquisition system has three humidity monitoring points and eight temperature monitoring points. Three of the temperature monitoring points are located with the humidity sensors. The major purpose of the temperature and humidity monitoring was to determine the relationship between HRV operation and humidity control, as well as the variation in temperatures and humidities throughout the dwelling unit.

An example of the data received to date from the monitoring equipment is included as Figures 5.3.1 to 5.3.6. Figure 5.3.1 shows the tracking of the three humidity sensors on a daily basis. Figure 5.3.2 shows the daily average temperatures of the three temperature sensors located at the same locations as the humidity sensors. Figures 5.3.3 and 5.3.4 show hourly average temperatures for a typical high ambient temperature day and low ambient temperature day, respectively. Figures 5.3.5 and 5.3.6 show the tracking of humidities on a typical warm day and a typical cold day, respectively.

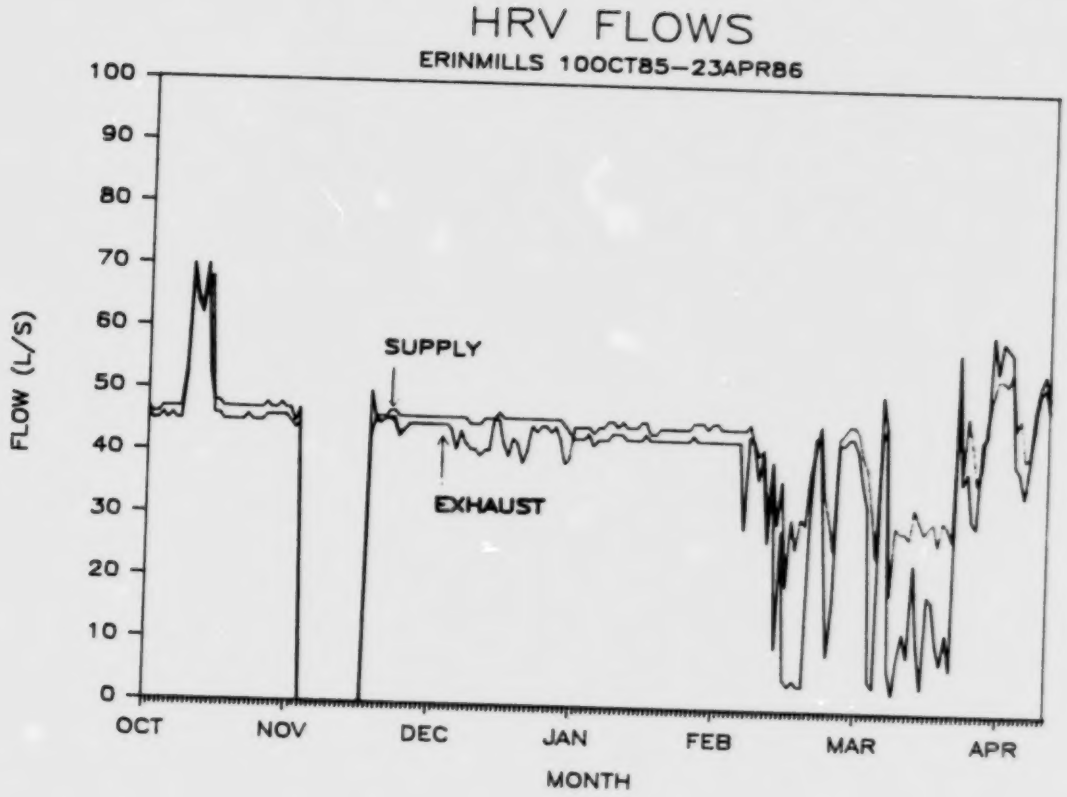

HRV FLOWS
ERINMILLS 10OCT85–23APR86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
SUPPLY
EXHAUST
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 5.2.14

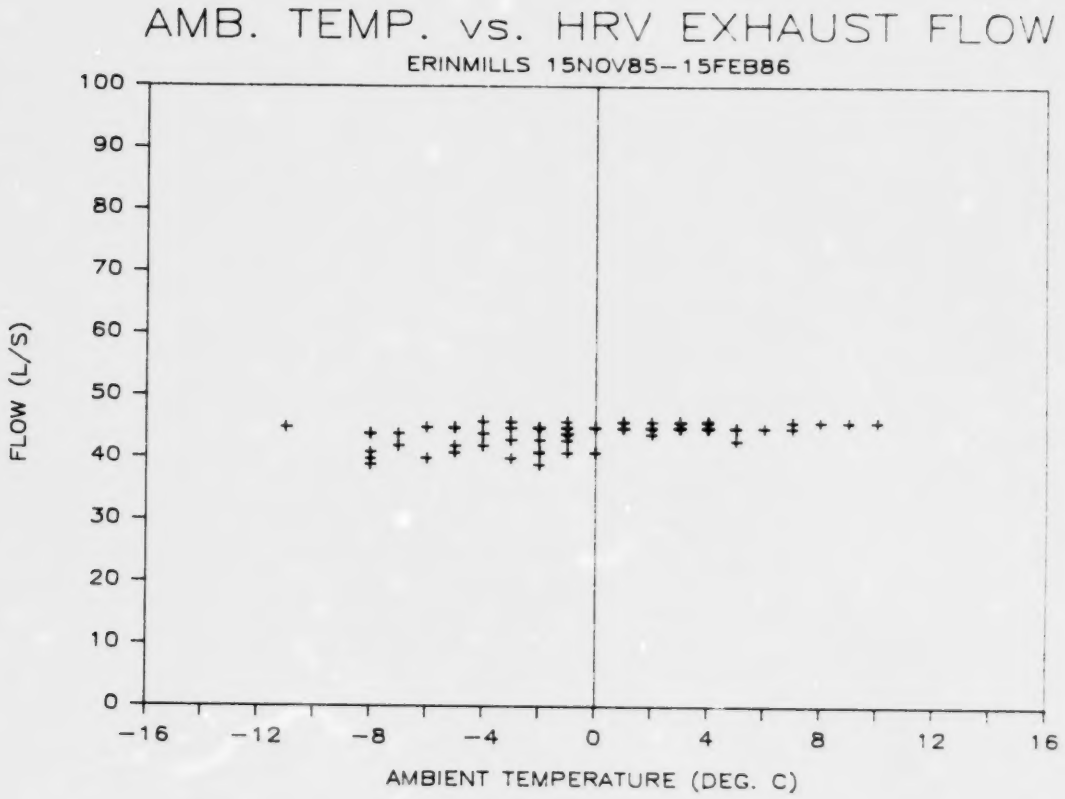

AMB. TEMP. vs. HRV EXHAUST FLOW
ERINMILLS 15NOV85–15FEB86
FLOW (L/S)
100
90
80
70
60
50
40
30
20
10
0
−16
−12
−8
−4
0
4
8
12
16
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.15

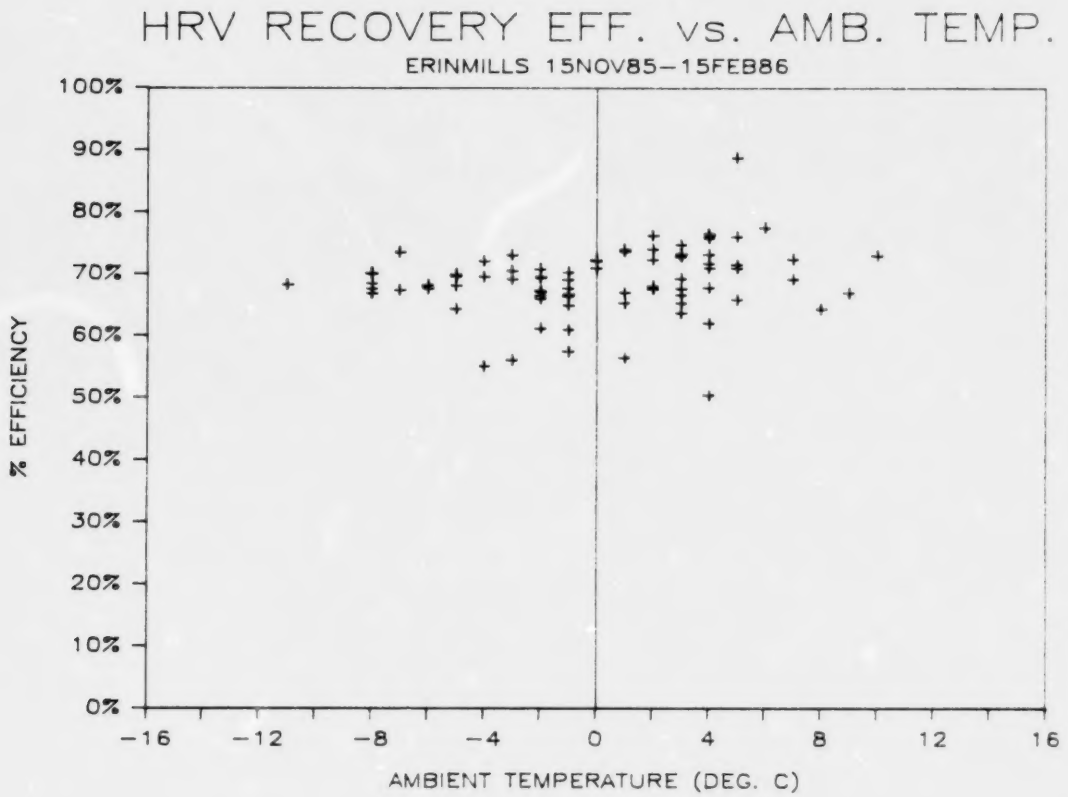

HRV RECOVERY EFF. vs. AMB. TEMP.
ERINMILLS 15NOV85–15FEB86
% EFFICIENCY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
−16
−12
−8
−4
0
4
8
12
16
AMBIENT TEMPERATURE (DEG. C)

FIGURE 5.2.16

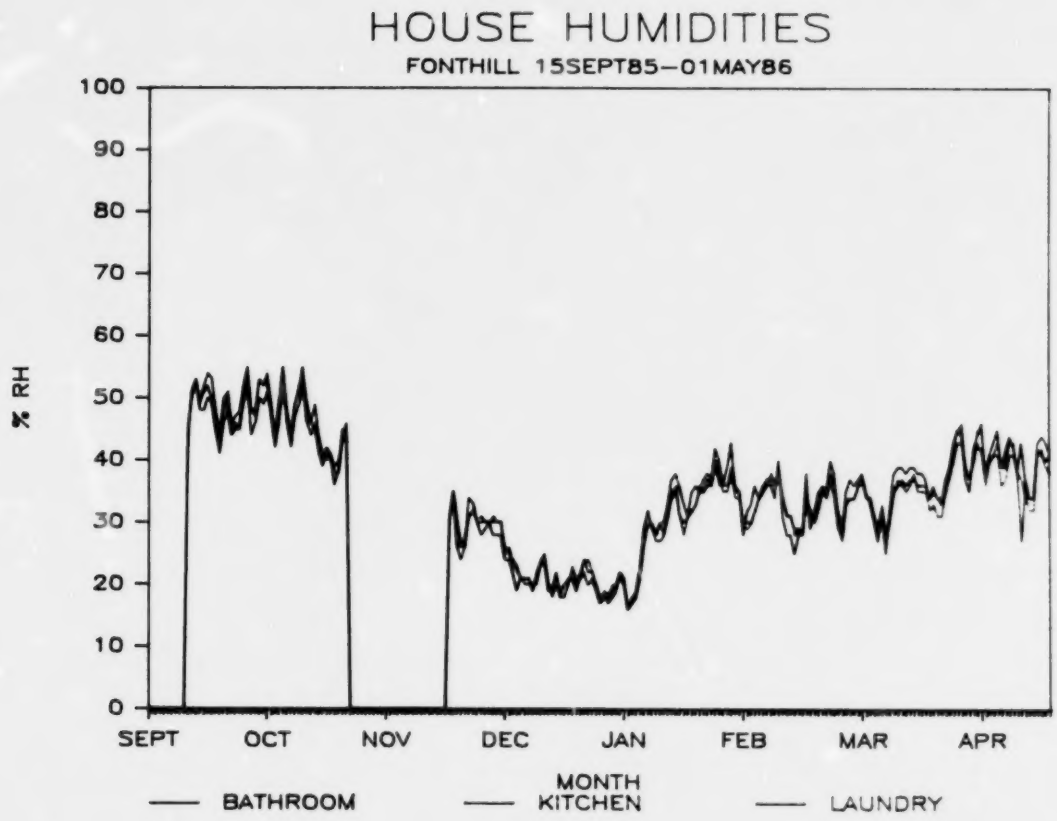

HOUSE HUMIDITIES
FONTHILL 15SEPT85–01MAY86
% RH
100
90
80
70
60
50
40
30
20
10
0
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH
BATHROOM
KITCHEN
LAUNDRY

FIGURE 5.3.1

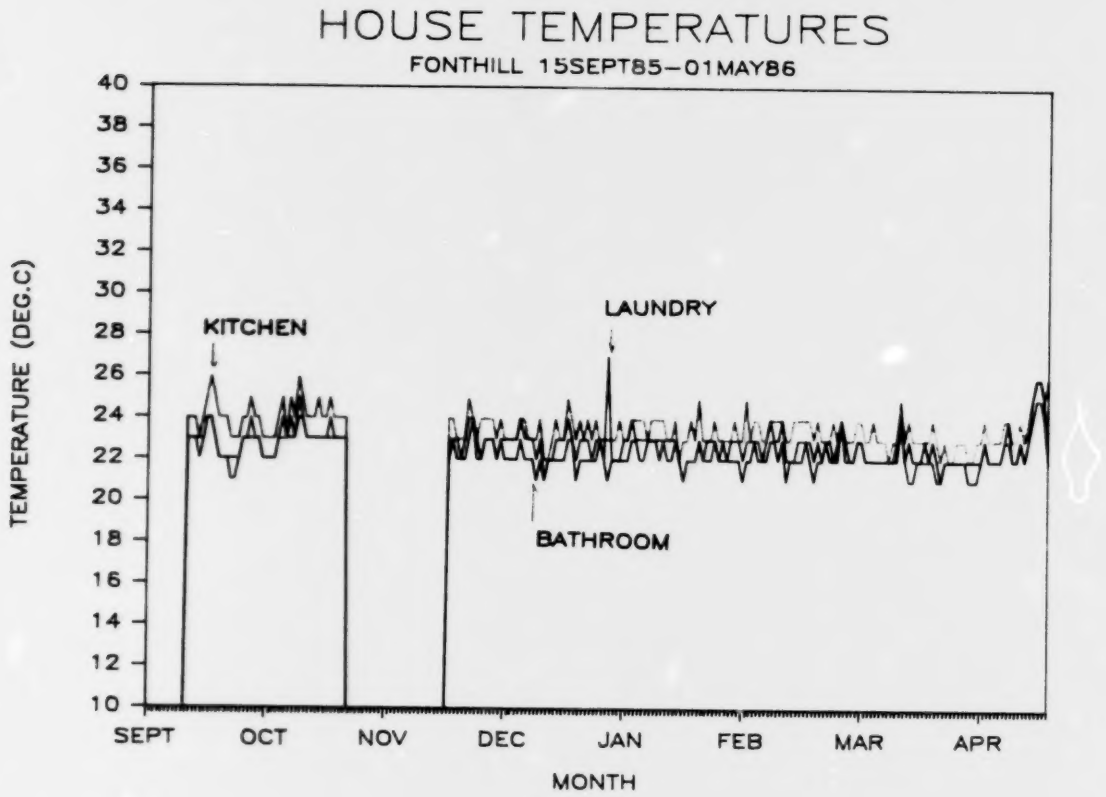

HOUSE TEMPERATURES
FONTHILL 15SEPT85–01MAY86
TEMPERATURE (DEG.C)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
KITCHEN
LAUNDRY
BATHROOM
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MONTH

FIGURE 5.3.2

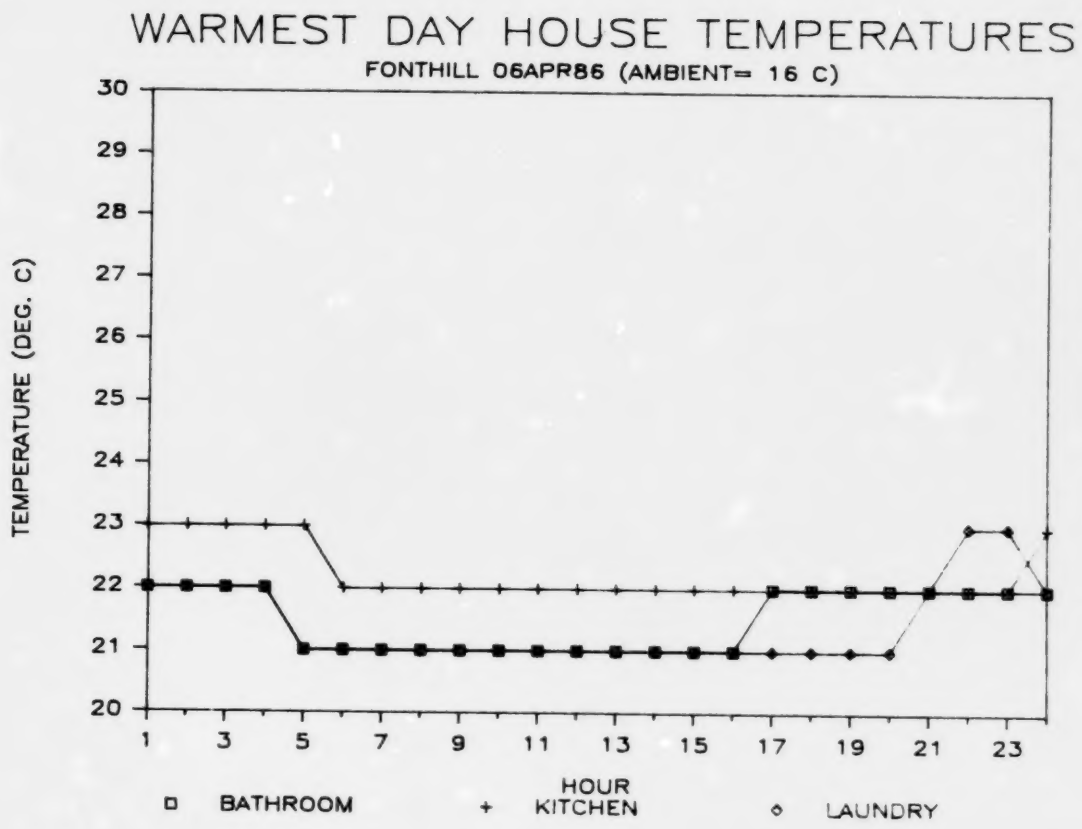

WARMEST DAY HOUSE TEMPERATURES
FONTHILL 06APR86 (AMBIENT= 16 C)
TEMPERATURE (DEG. C)
30
29
28
27
26
25
24
23
22
21
20
1
3
5
7
9
11
13
15
17
19
21
23
HOUR
BATHROOM
KITCHEN
LAUNDRY

FIGURE 5.3.3

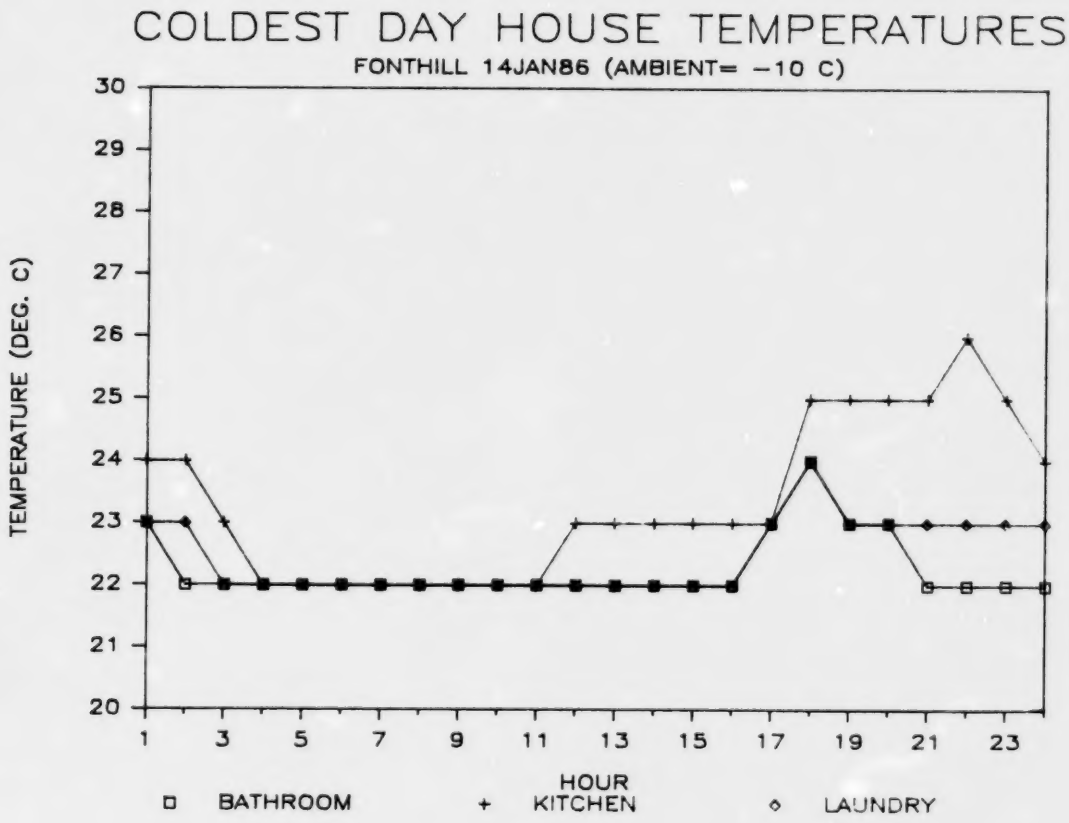

COLDEST DAY HOUSE TEMPERATURES
FONTHILL 14JAN86 (AMBIENT= −10 C)
TEMPERATURE (DEG. C)
30
29
28
27
26
25
24
23
22
21
20
1
3
5
7
9
11
13
15
17
19
21
23
HOUR
BATHROOM
KITCHEN
LAUNDRY

FIGURE 5.3.4

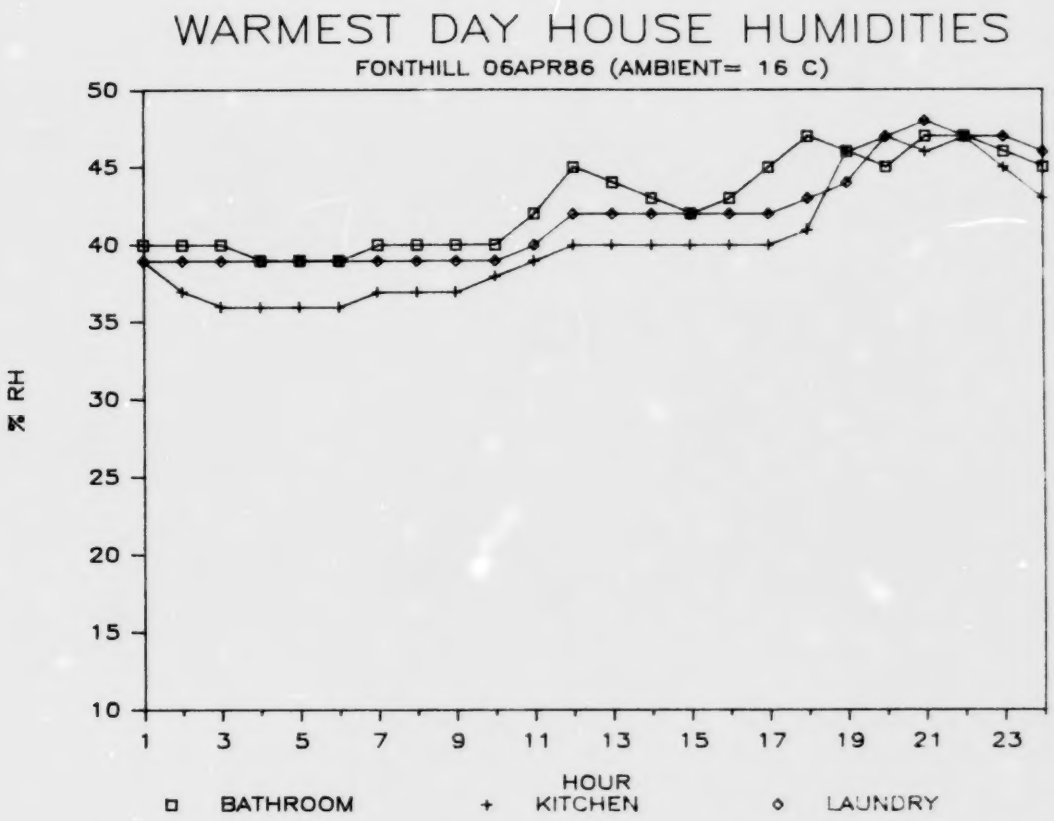

WARMEST DAY HOUSE HUMIDITIES
FONTHILL 06APR86 (AMBIENT= 16 C)
% RH
50
45
40
35
30
25
20
15
10
1
3
5
7
9
11
13
15
17
19
21
23
HOUR
BATHROOM
KITCHEN
LAUNDRY

FIGURE 5.3.5

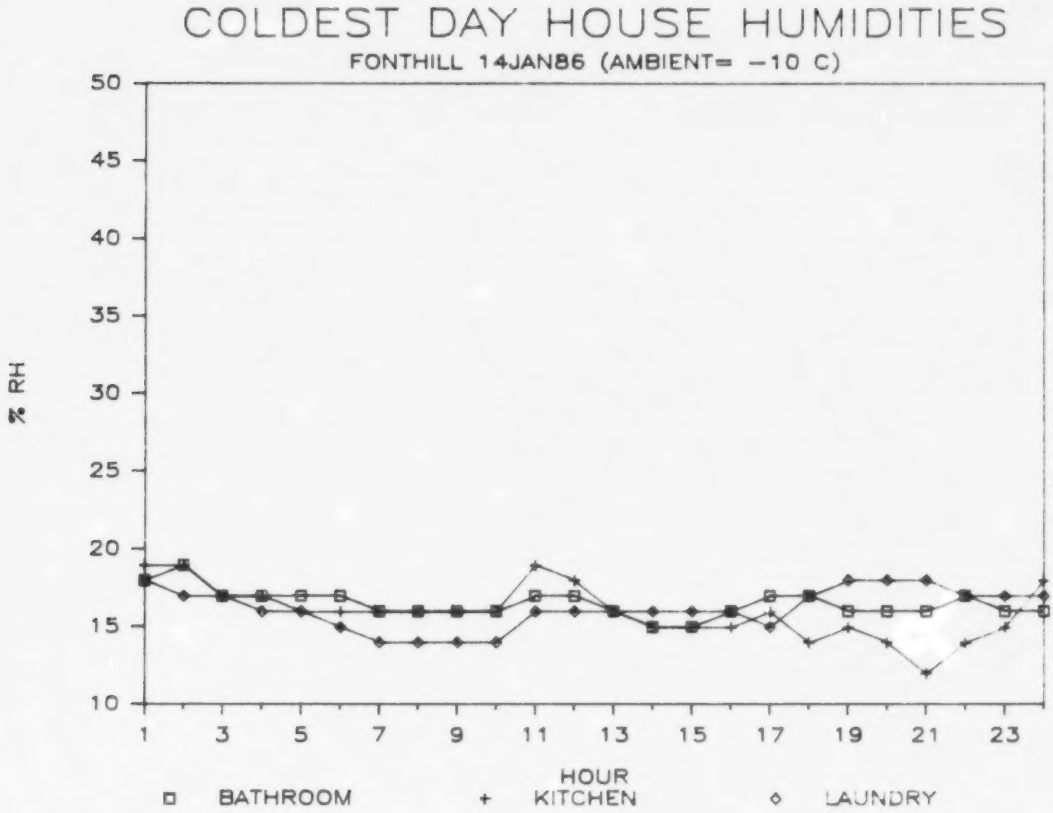

COLDEST DAY HOUSE HUMIDITIES
FONTHILL 14JAN86 (AMBIENT= -10 C)
% RH
50
45
40
35
30
25
20
15
10
1
3
5
7
9
11
13
15
17
19
21
23
HOUR
BATHROOM
KITCHEN
LAUNDRY

FIGURE 5.3.6

6.0 HOMEOWNER FEEDBACK

6.1 Formal Questionnaire Response

In order to ensure compatibility of homeowner data with the Federal R-2000 program, the general Federal R-2000 questionnaire forms were used throughout this monitoring program. Two specific homeowner questionnaires are available for R-2000 homeowners. The first questionnaire is an initial survey of the homeowner's profile and concerns and expectations related to the R-2000 home. The second questionnaire is a follow-up questionnaire used to document ongoing concerns and changes in attitude towards the R-2000 home.

In order for this information to be useful, it must be collected from a large sample of R-2000 occupants and tracked over a significant period of time. The only data available for this specific monitoring program consists of the data for the twenty two R-2000 homes with one follow-up questionnaire.

Samples of the questionnaire forms are included as Appendix F.

It is not easy to judge the degree to which the occupants of these twenty two houses are typical of the average Ontario resident. Because of the nature of the R-2000 program, it is likely that these people are, on average, more concerned with housing quality issues and energy efficiency.

From the formal questionnaires, it is difficult to draw many significant conclusions, however, Table 6.1.1 illustrates one major area of concern. This table relates, on a percentage basis, the number of occupants who claim they would buy another R-2000 house. In September of 1985, one hundred percent of the occupants in all four communities stated that they would consider the purchase of another R-2000 home. After a substantial portion of the heating season had passed, this percentage had dropped in Sudbury by twenty percent, in Fonthill by sixty percent, and in Erin Mills by seventy percent. Only in Kingston did all five occupants in the sample state that they would buy another R-2000 home.

The higher than expected energy costs and air distribution problems in the Erin Mills units contributed to the change in the occupants' attitudes towards R-2000 homes in that part of the sample. Specific problems,

TABLE 6.1.1 PERCENTAGE OF OCCUPANTS WHO WOULD BUY ANOTHER R-2000 HOUSE

	September 1985	March 1986
Sudbury	100	80
Kingston	100	100
Fonthill	100	40
Erin Mills	100	30

unrelated to the R-2000 aspects of the houses in Fonthill, such as the water entry problem at House B, were responsible for most of the attitude changes in that portion of the sample.

The changes in homeowner attitudes towards their R-2000 houses are directly related to the number of complaints and specific concerns put forward by the homeowners in the various communities.

6.2 Specific Concerns

In addition to the basic R-2000 questionnaire, supplemental questionnaires were produced to ask homeowners to describe specific observations about their R-2000 houses.

The method of questioning prompted occupants to give answers of yes, they had observed a specific problem, or no, they had not observed a specific problem. In addition, if a yes answer was given the occupant was asked to quantify the size of the problem as significant or minor.

From these responses, Table 6.2.1 was generated. It lists the specific problems expressed during the interviews with each occupant. They are listed in descending order according to the number of specific incidences that the item was mentioned as a concern.

TABLE 6.2.1 SPECIFIC OCCUPANT OBSERVATIONS
(In Order of Frequency)

	Significant Problem	Minor Problem
Dust	9	3
Air Distribution	8	0
Dryness	5	3
Furnace Noise	4	2
Stuffiness	3	1
Energy Cost	3	0
High Humidity	1	2
Drafts	1	0
Odours	1	0

7.0 CONCLUSIONS AND RECOMMENDATIONS

This report has been generated at a relatively early stage in a long-term monitoring program. Approximately eight months of monitoring data has been obtained. Over that same period, a significant effort has been expended in the commissioning and troubleshooting of instrumentation systems, and the calibration of sampling devices. In spite of these limitations, a substantial amount of information has been obtained concerning the operation of this group of R-2000 houses. The profile of the houses varies greatly from one community to another. The houses in Sudbury most closely correspond with the R-2000 requirements in effect at the time of their approval. Energy consumption figures and air change rates at 50 pascals closely match the then current R-2000 requirements. The ventilation rates in these units, however, are generally below those required by the R-2000 program at the time.

The units in Erin Mills, on average, display very high energy consumption rates for space heating and significant deviations from the required 1.5 air changes per hour at 50 pascals. Ventilation rates, generally, meet the R-2000 requirements.

The houses in Kingston and Fonthill, with the exception of those retrofitted with Air Changer DR-275 heat recovery ventilators, exhibit significantly low ventilation rates. Energy consumption in the houses is significantly in excess of the HOTCAN predictions. The Kingston houses, generally, meet the air change requirements of 1.5 air changes per hour at 50 pascals whereas Fonthill units all exceed these requirements with one unit substantially in excess of the 1.5 ACH criterion.

Throughout the sample of the twenty two houses, the thermographic scan results indicate generally similar air leakage and thermal conduction characteristics. The Erin Mills units are one exception where several significant thermal conduction paths appear to exist. It appears that a significant portion of the problems associated with the twenty two units stem from a lack of understanding, on the part of the builders and system installers, of the equipment and systems with which they were dealing. Many of the problems have likely been rectified and would not appear in later model units due to the much more comprehensive training system now available for R-2000 builders and R-2000 equipment installers.

The specific problems associated with the Erin Mills units appear to stem from inadequate control of the building construction, before and after the

acceptance of the units. The HOTCAN predictions were based on base unit designs before the installation of consumer preference items such as skylights and additional fireplaces. A major issue concerns the initial method of depressurization testing, particularly associated with the four units being monitored in Block I of the Erin Mills development.

The monitored energy data exhibits significant variations from the HOTCAN predictions. Even in a sample such as the five Sudbury units where the average consumption for space heating is within ten percent of the HOTCAN predictions, the space heating consumption still ranges from fifteen percent less than that predicted by HOTCAN to thirty-two percent in excess of the HOTCAN predictions. This data clearly shows the problems that can be associated with the program if HOTCAN predictions are relayed to potential home buyers and used as a selling feature for the houses.

It is likely that the recalculation of the theoretical energy consumption of these units using the much enhanced HOT 2000 program would yield somewhat more realistic energy consumption results.

The extensive air quality monitoring undertaken to date has indicated that these R-2000 homes exhibit no significant air quality problems related to any of the four contaminants being measured. Because of the relatively short span of data available, however, detailed correlations of significant derivations from the average concentrations found have not been made.

Carbon dioxide concentrations appear to show a significant dependence on the time of year where formaldehyde concentrations appear to be dependent on the age of the dwelling unit. The future analysis of data will be used to further investigate these and other trends.

The detailed monitoring program has produced initial results on the in-the-field performance of three different models of heat recovery ventilators. Significant findings indicate that the time spent under defrost conditions is less than expected and the operation of these units under high speed conditions is less than expected. These units have been running, with the exception of the exchange of Air Changer DR-150 end panels for Air Changer DR-275 end panels in Fonthill and Kingston, as originally installed by the builders. In all cases, some deficiencies in the HRV installations exist.

Homeowner satisfaction with these R-2000 units is far from enthusiastic in two of the four communities being monitored, Erin Mills and Fonthill. The

very good response by homeowners in Sudbury and Kingston indicate that, with the proper initial construction of the units, realistic expectations on the part of the homeowners and good builder follow-up, a high degree of integrity in the program can be maintained.

Some specific upgrading of heat recovery ventilator systems must be undertaken in any units showing substandard flow rates or significant operational problems with the HRV units.

Although not directly related to the R-2000 portion of the program, the heat distribution problem in the Erin Mills units should be addressed.

The general recommendations associated with the follow-on portion of this monitoring program are that the monitoring program be carried on in an essentially unaltered fashion.

APPENDIX A

HOUSE PROFILES

HOUSE A, SUDBURY, ONTARIO

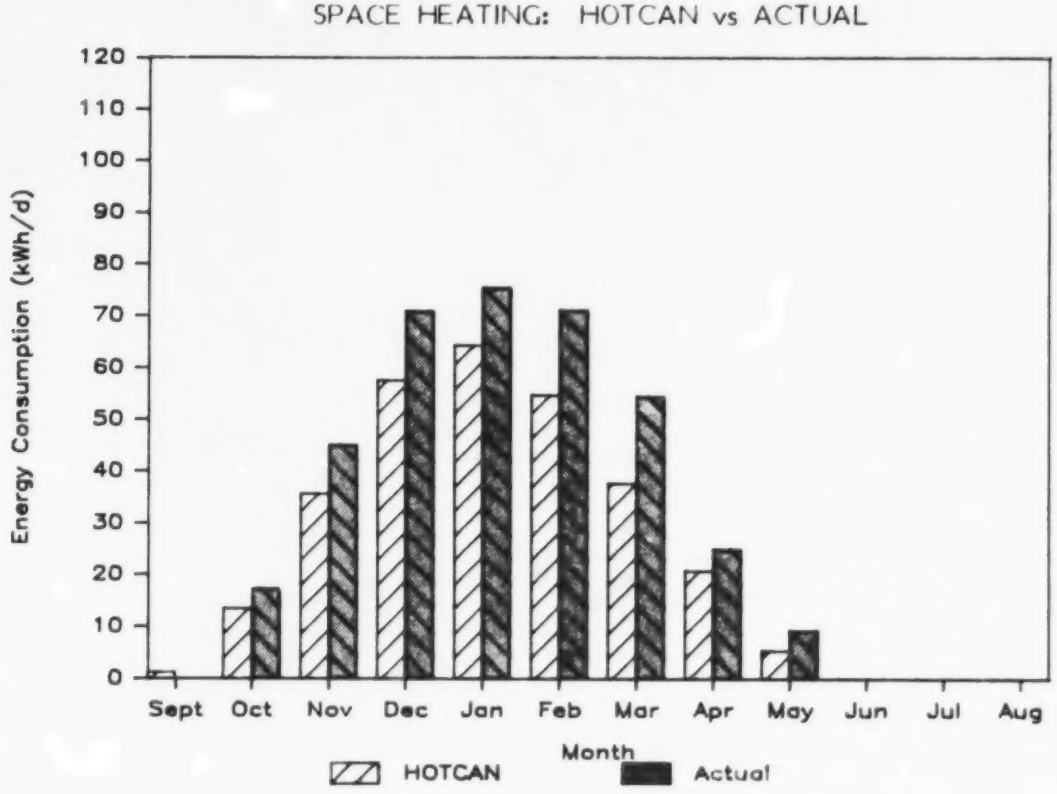
Type of House: Side Split - Full Basement

Appliances (Make & Type)
- Furnace: Electric baseboard
- DHW Heater: John Wood - electric (40 gallon)
- Fireplace(s): One

Floor Area: 199.2 m^2

Homeowner Profile

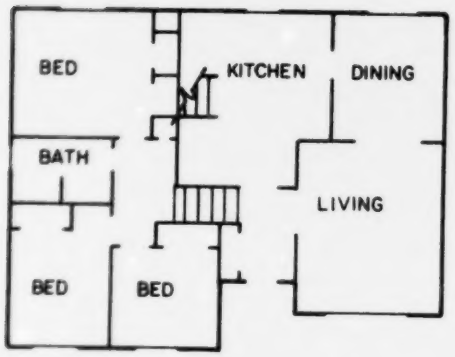
Age of owner: 18 - 30	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 1	Children: 2	



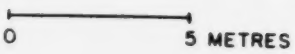
Hotcan Predictions
- Space Heating: 8,809 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

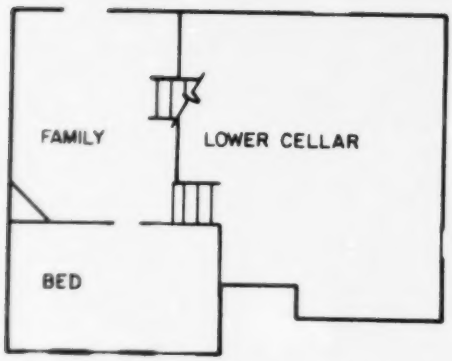
Actual (extrapolated) Space Heating: 11,200 kWh

HOUSE A, SUDBURY



UPPER FLOOR AND MIDDLE FLOOR





LOWER FLOOR AND BASEMENT

HOUSE B, SUDBURY, ONTARIO

Type of House: Bungalow - Full basement

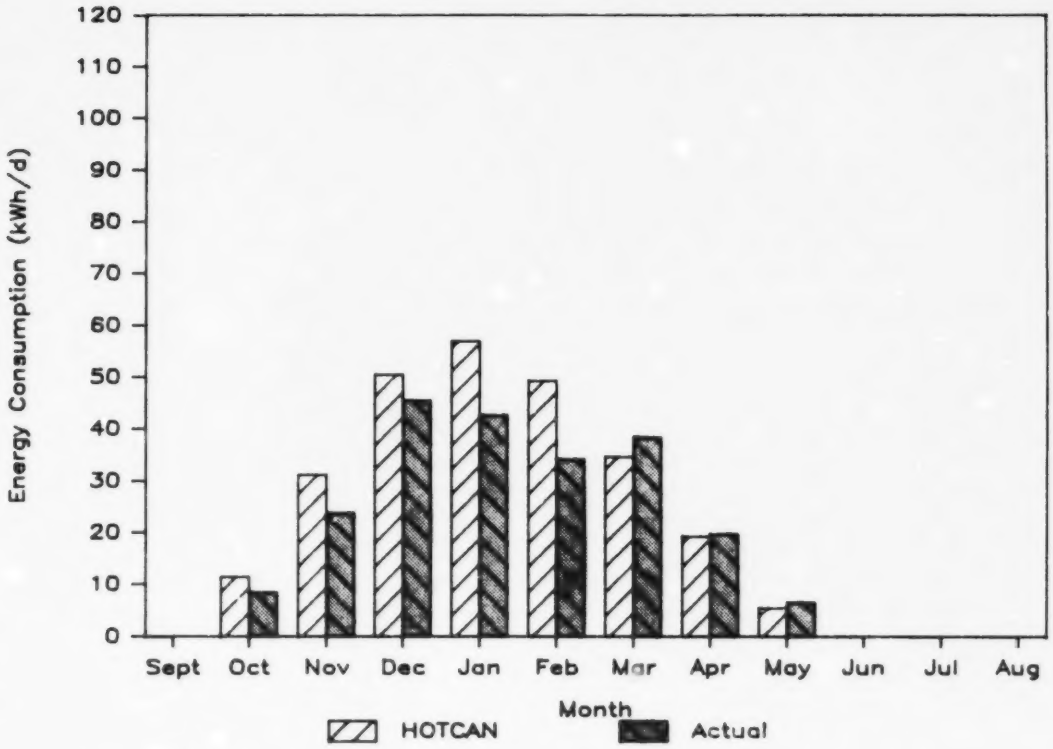
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): No

Floor Area: 199.2 m^2

Homeowner Profile

Age of owner:	31 - 45	Age of Spouse:	18 - 30
Number of occupants:		Adults: 2	Children: 3
Number home during the day:		Adults: 1	Children: 2

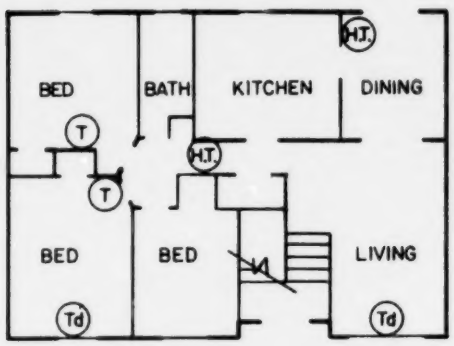
SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 7,866 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

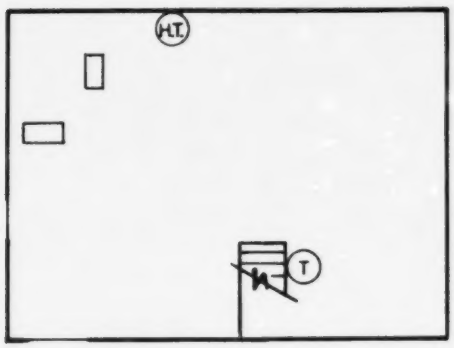
Actual (extrapolated) Space Heating: 6,698 kWh

HOUSE B, SUDBURY



GROUND FLOOR

0 5 METRES



BASEMENT

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

HOUSE C, SUDBURY, ONTARIO

Type of House: Bungalow - Full Basement

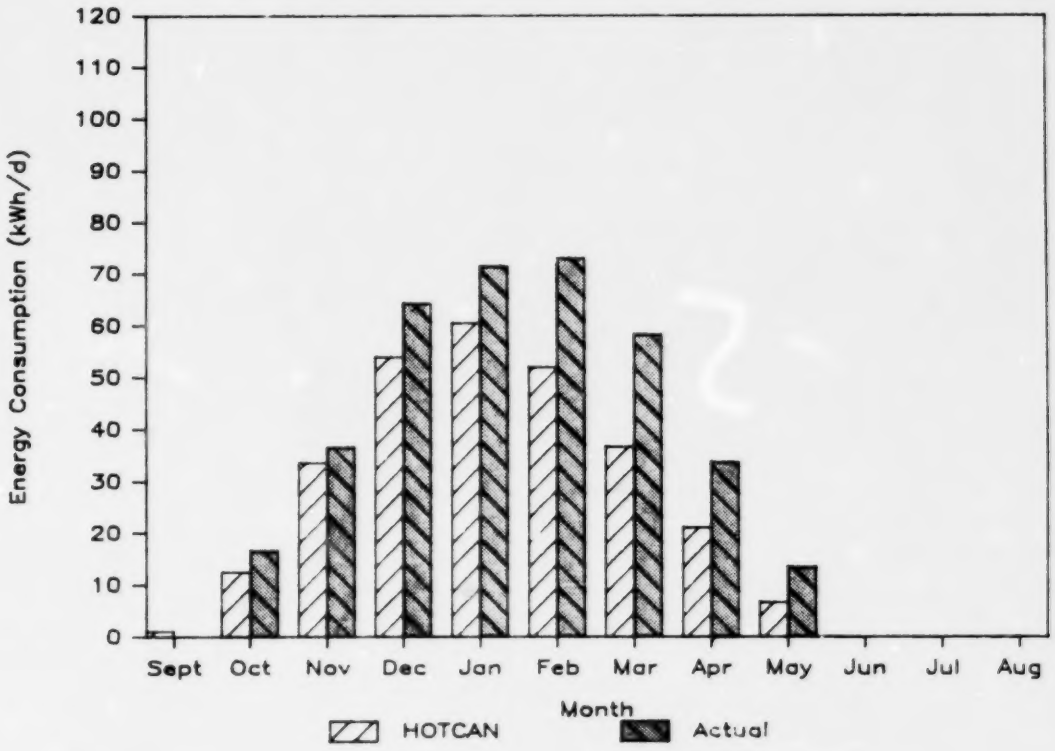
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: Rheem - natural gas
- Fireplace(s): No

Floor Area: 199.2 m^2

Homeowner Profile

Age of owner:	31 - 45	Age of Spouse:	31 - 45	
Number of occupants:		Adults: 2		Children: 2
Number home during the day:		Adults: 1		Children: 1

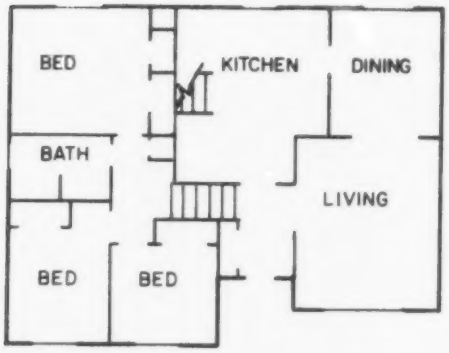
SPACE HEATING: HOTCAN vs ACTUAL



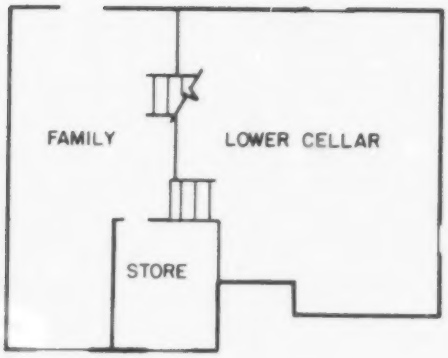
Hotcan Predictions
- Space Heating: 8,432 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 11,163 kWh

HOUSE C, SUDBURY



UPPER FLOOR AND MIDDLE FLOOR



LOWER FLOOR AND BASEMENT

HOUSE D, SUDBURY, ONTARIO

Type of House: Side Split - Full basement

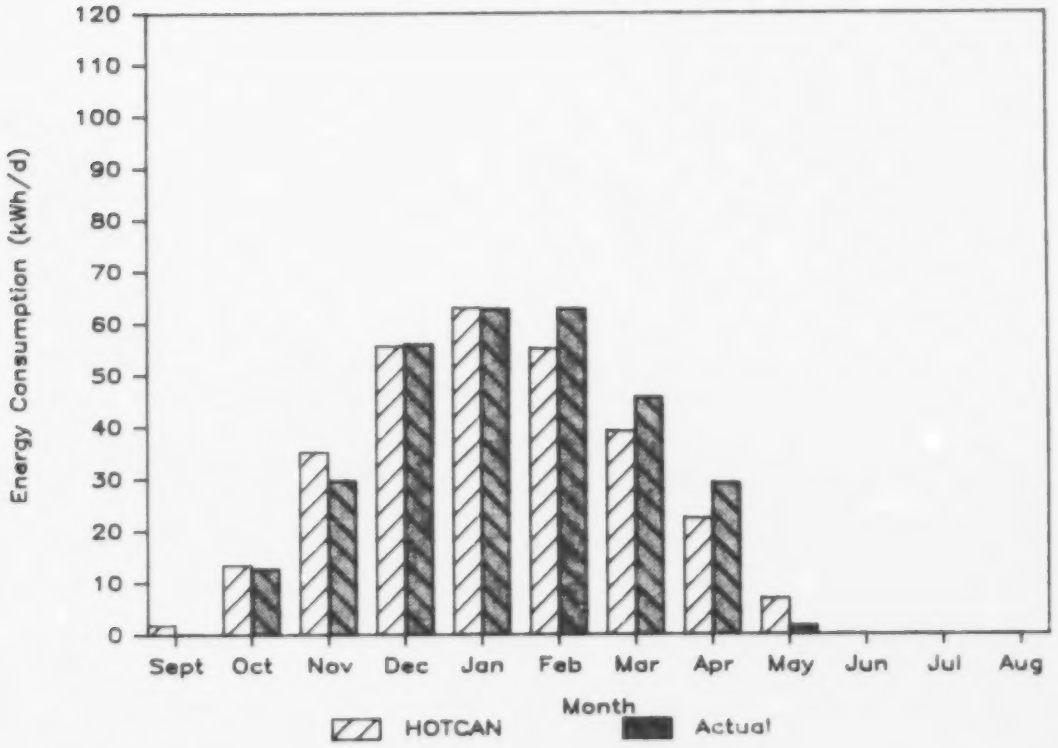
Appliances (Make & Type)
- Furnace: Olsen Minimax - natural gas
- DHW Heater: John Wood - electric
- Fireplace(s): No

Floor Area: 202.1 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 2	
Number home during the day:	Adults: 1	Children: 0	

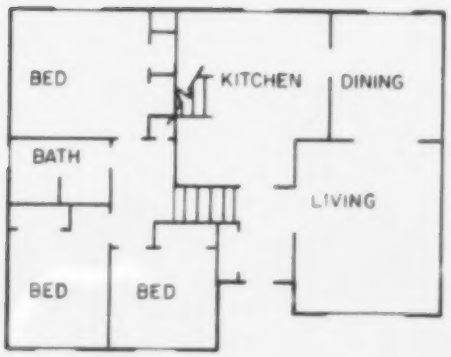
SPACE HEATING: HOTCAN vs ACTUAL



Hotcan Predictions
- Space Heating: 8,851 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

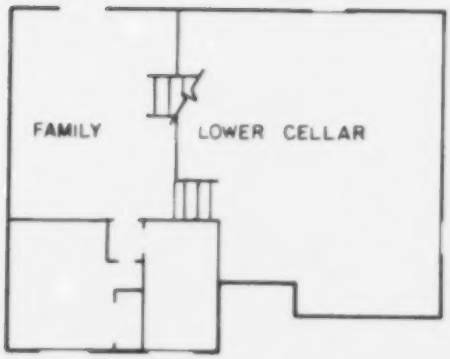
Actual (extrapolated) Space Heating: 9,137 kWh

HOUSE D, SUDBURY



UPPER FLOOR AND MIDDLE FLOOR

0 5 METRES



LOWER FLOOR AND BASEMENT

HOUSE E, SUDBURY, ONTARIO

Type of House: Back Split - Full basement

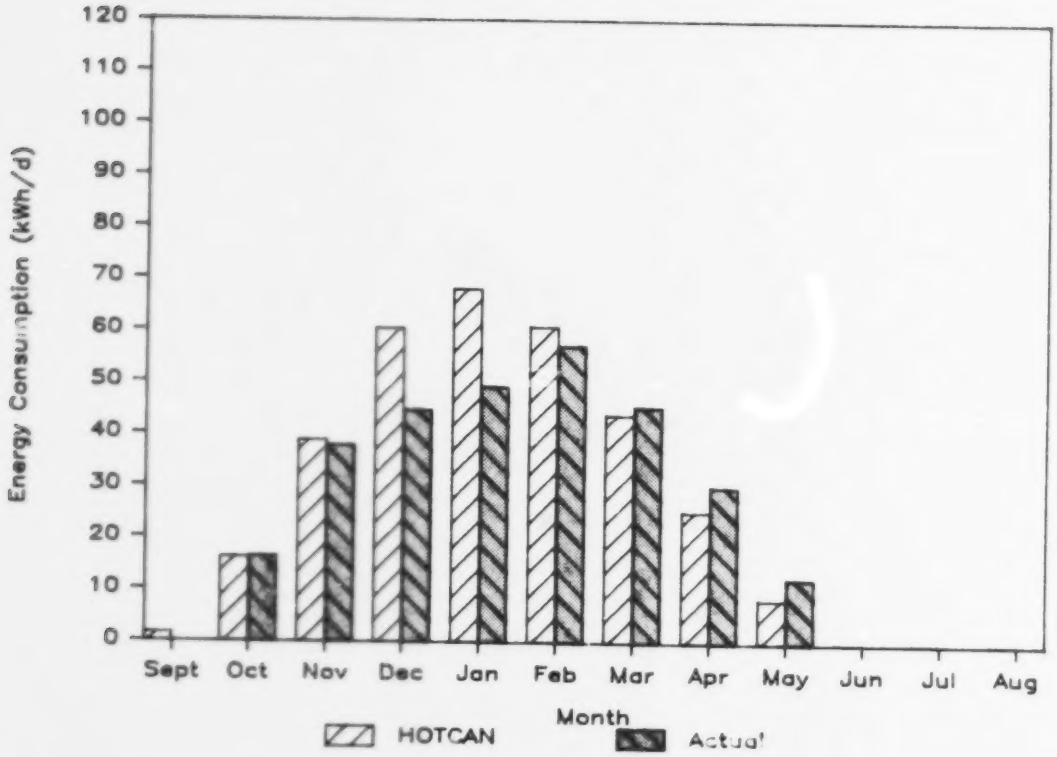
Appliances (Make & Type)
- Furnace: Olsen Duomatic Ultramax - natural gas
- DHW Heater: Rheems - electric
- Fireplace(s): One

Floor Area: 222.9 m^2

Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

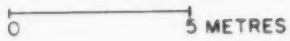


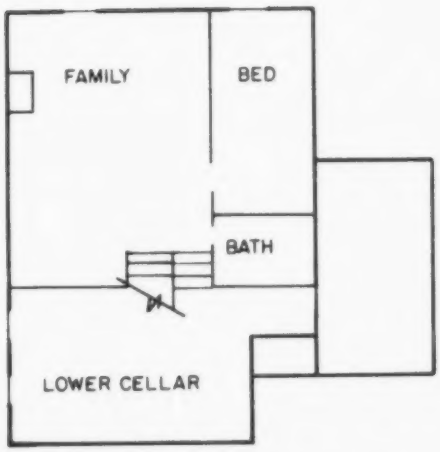
Hotcan Predictions
- Space Heating: 9,782 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 8,936 kWh

HOUSE E, SUDBURY

UPPER FLOOR AND MIDDLE FLOOR





LOWER FLOOR AND BASEMENT

HOUSE A, KINGSTON, ONTARIO

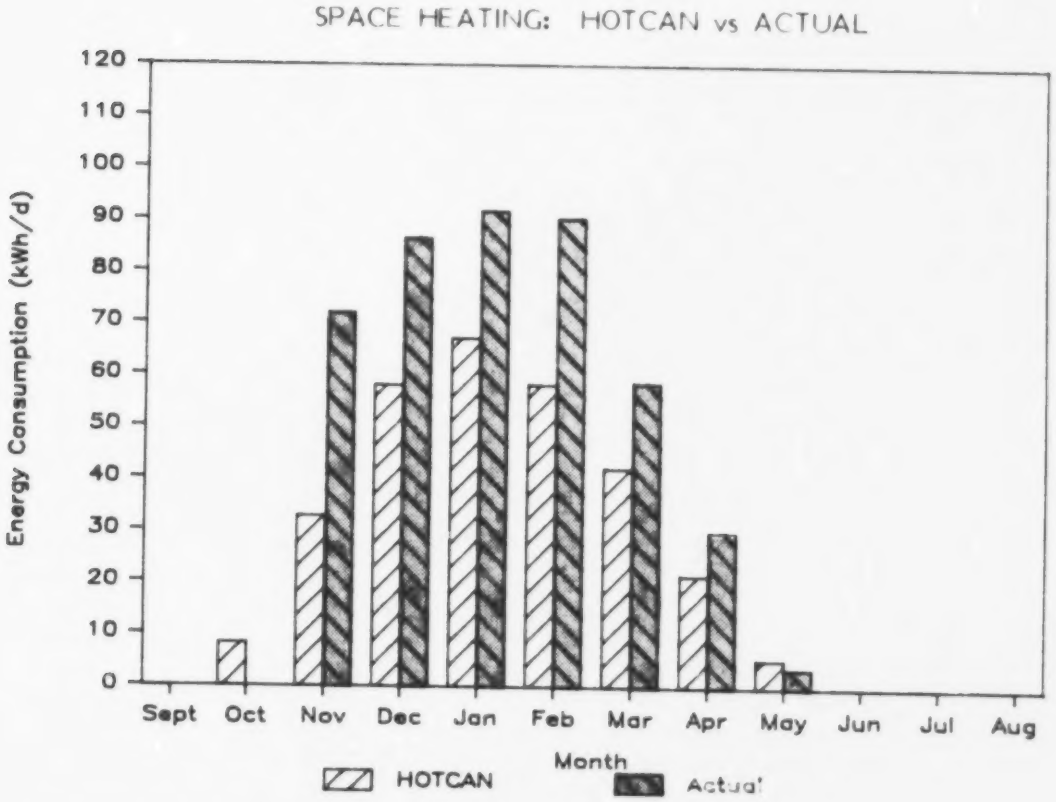
Type of House: 2 Storey - Full basement

Appliances (Make & Type)
- Furnace: Summeraire - electric
- DHW Heater: John Wood - electric
- Fireplace(s): One

Floor Area: 284.2 m^2

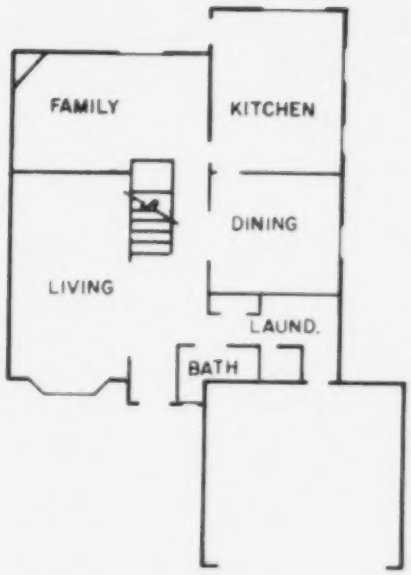
Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

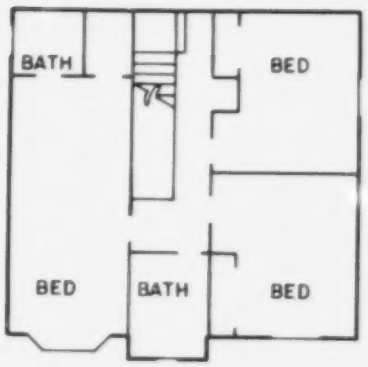


Hotcan Predictions
- Space Heating: 8,881 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 13,472 kWh



GROUND FLOOR



SECOND FLOOR

0 5 METRES

BASEMENT

HOUSE A, KINGSTON

HOUSE B, KINGSTON, ONTARIO

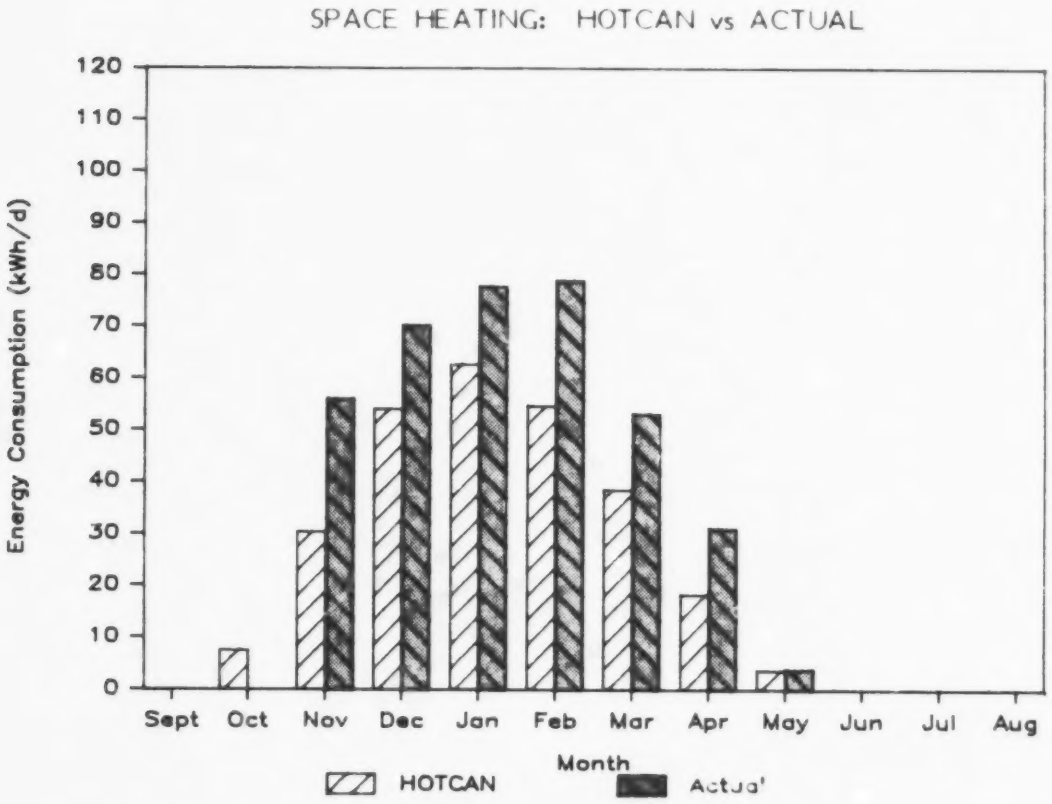
Type of House: 2 Storey - Full Basement

Appliances (Make & Type)
- Furnace: Lennox - electric
- DHW Heater: Ruud - electric
- Fireplace(s): One

Floor Area: 258.8 m^2

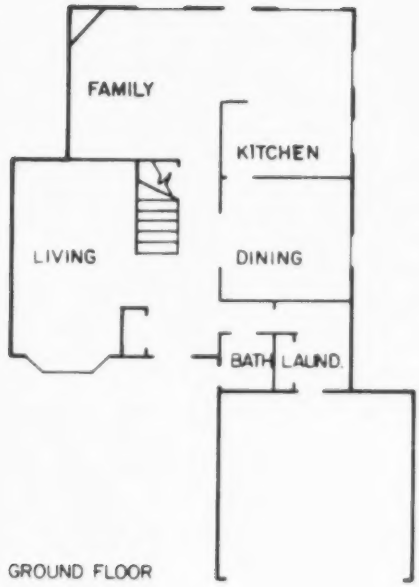
Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 2	
Number home during the day:	Adults: 0	Children: 0	

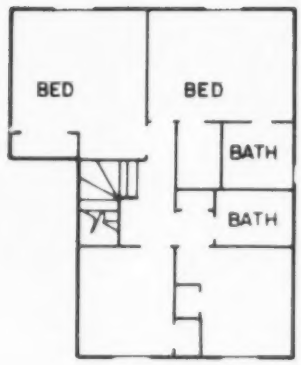


Hotcan Predictions
- Space Heating: 8,170 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

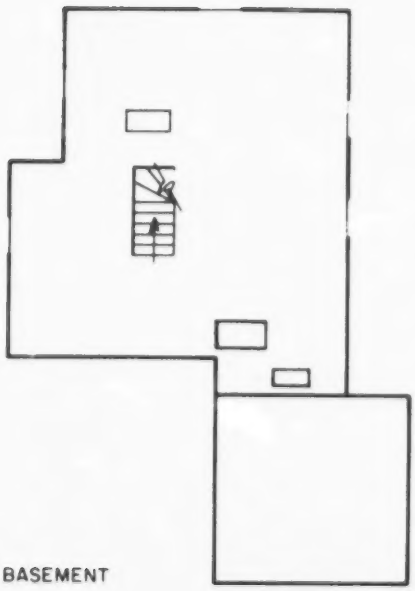
Actual (extrapolated) Space Heating: 11,562 kWh



GROUND FLOOR



SECOND FLOOR



BASEMENT

HOUSE B, KINGSTON

HOUSE C, KINGSTON, ONTARIO

Type of House: 2 Storey - Full basement

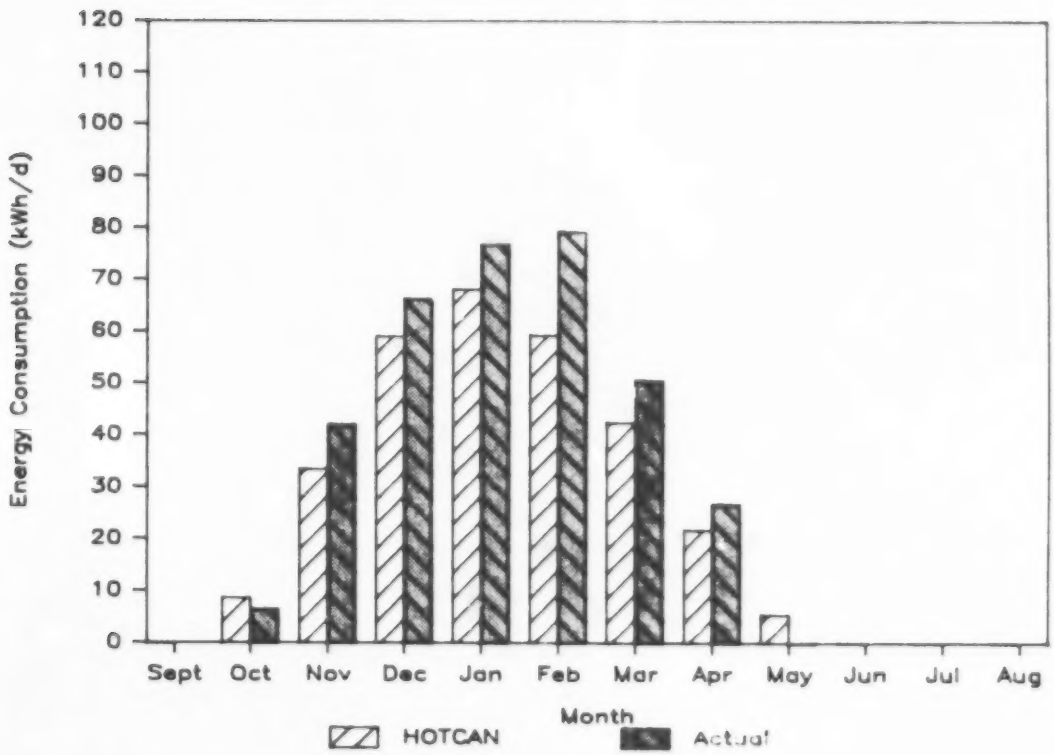
Appliances (Make & Type)
- Furnace: Lennox - electric
- DHW Heater: Rheem - electric
- Fireplace(s): one

Floor Area: 269.6 m^2

Homeowner Profile

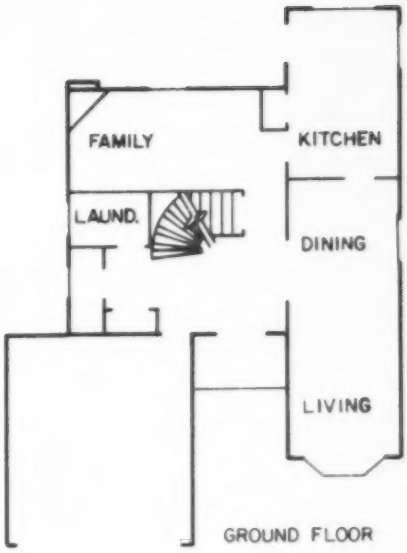
Age of owner: 46 - 60	Age of Spouse: 46 - 60		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

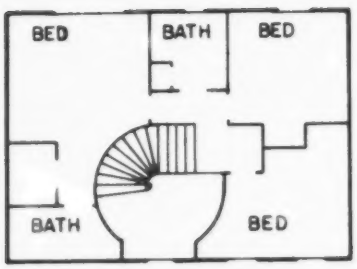
SPACE HEATING: HOTCAN vs ACTUAL

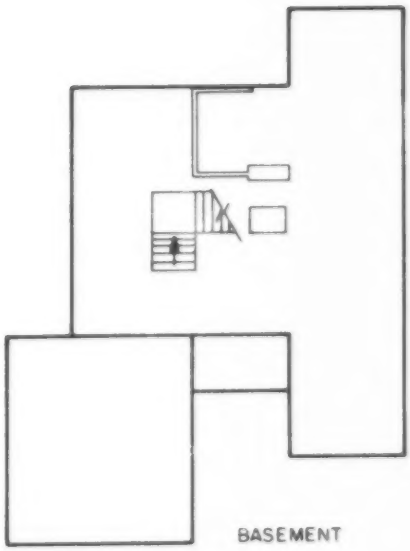


Hotcan Predictions
- Space Heating: 9,021 kWI
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 10,521 kWh







HOUSE C, KINGSTON

HOUSE D, KINGSTON, ONTARIO

Type of House: 2 Storey - Full basement

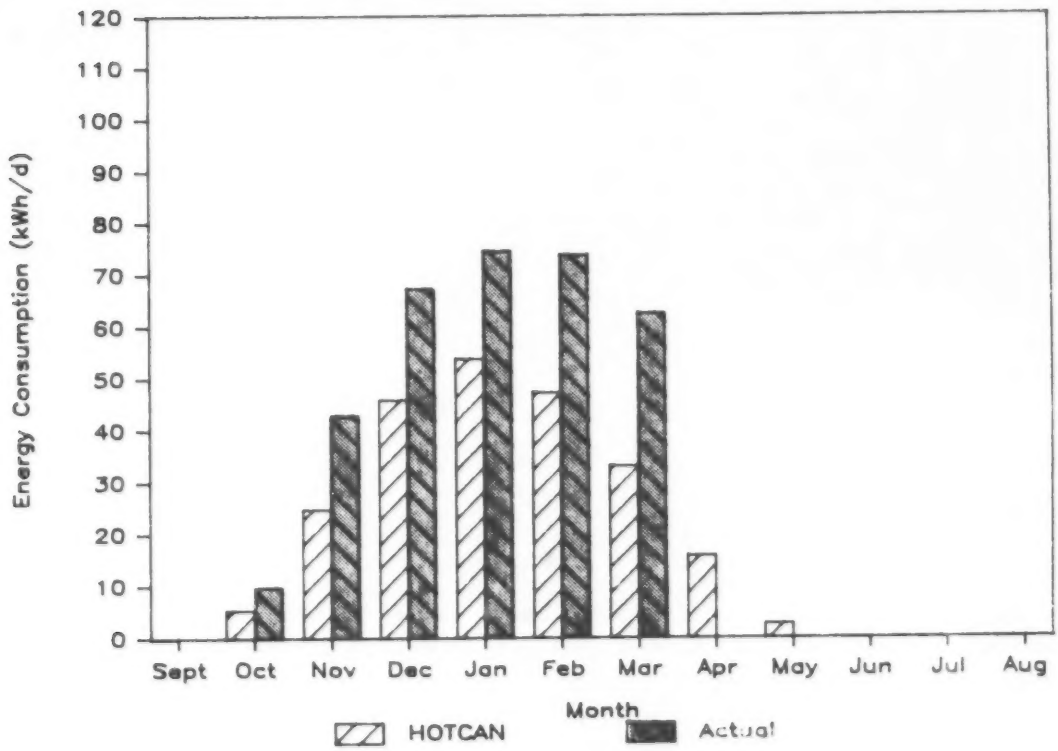
Appliances (Make & Type)
- Furnace: Luxaire (Borg Warner) - electric
- DHW Heater: Ruud - electric
- Fireplace(s): One

Floor Area: 217.1 m^2

Homeowner Profile

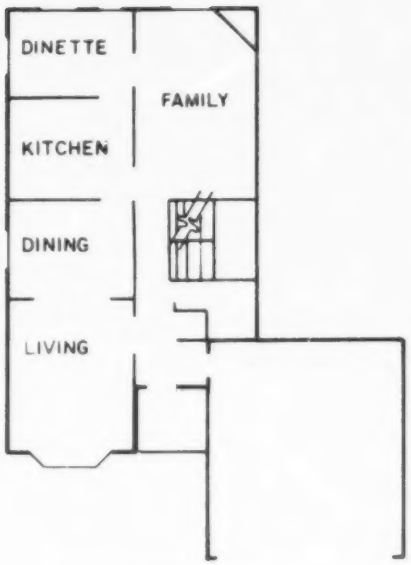
Age of owner: 31 - 45	Age of Spouse: 18 - 30		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

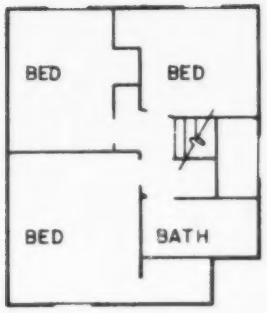


Hotcan Predictions
- Space Heating: 6,935
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 10,907 kWh



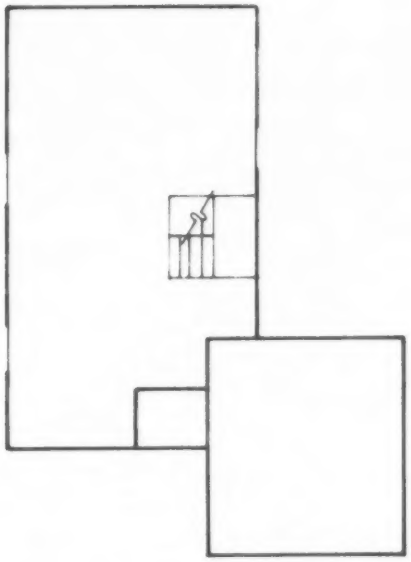
GROUND FLOOR



SECOND FLOOR

0 5 METRES

HOUSE D, KINGSTON



BASEMENT

HOUSE E, KINGSTON, ONTARIO

Type of House: 2 Storey - Full Basement

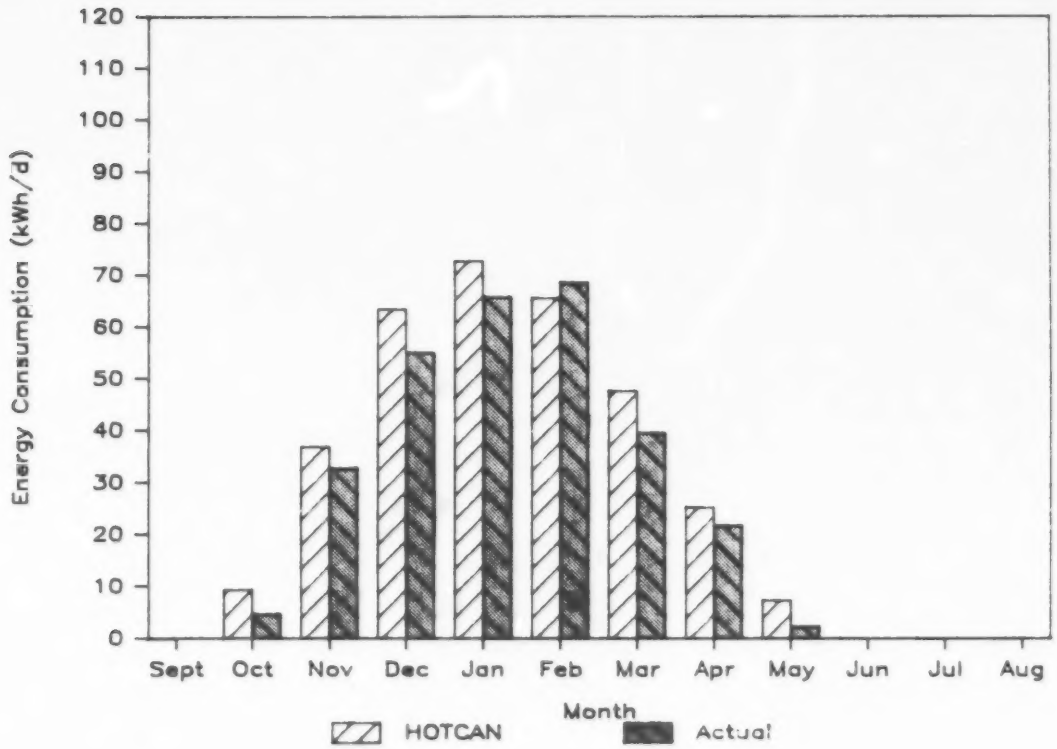
Appliances (Make & Type)
- Furnace: Lennox Pulse - natural gas
- DHW Heater: Ruud - electric
- Fireplace(s): One

Floor Area: 284.2 m^2

Homeowner Profile

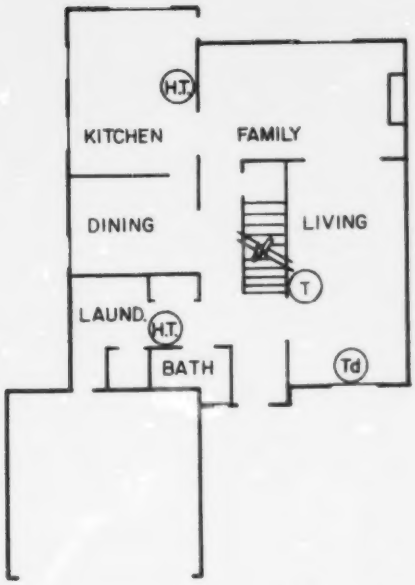
Age of owner:	46 - 60	Age of Spouse:	46 - 60
Number of occupants:		Adults: 2	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL

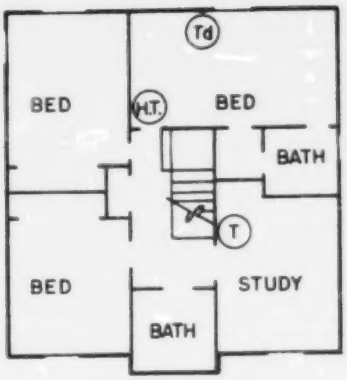


Hotcan Predictions
- Space Heating: 9,920 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

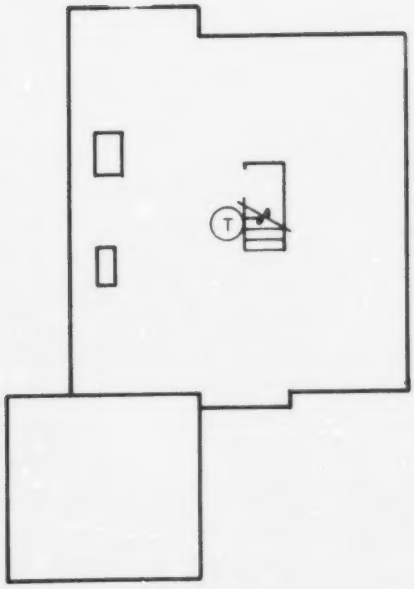
Actual (extrapolated) Space Heating: 8,748 kWh



GROUND FLOOR



SECOND FLOOR



BASEMENT

HOUSE E, KINGSTON

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

HOUSE A, FONTHILL, ONTARIO

Type of House: 2 Storey - Full basement

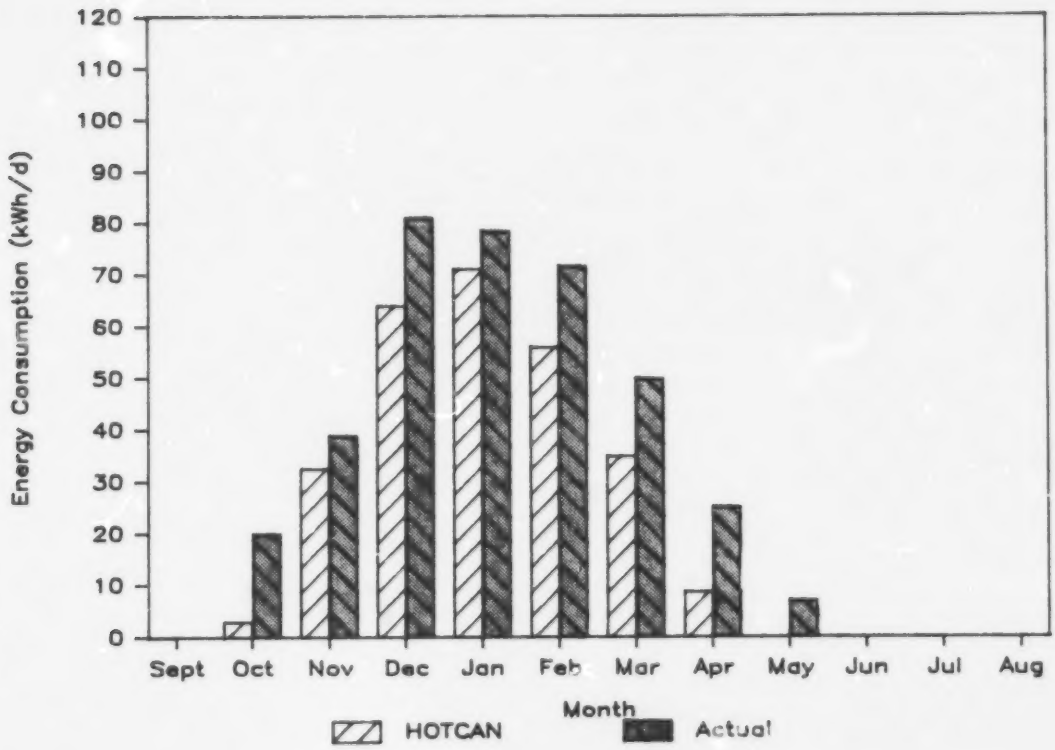
Appliances (Make & Type)
- Furnace: York - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): One

Floor Area: 290.0 m^2

Homeowner Profile

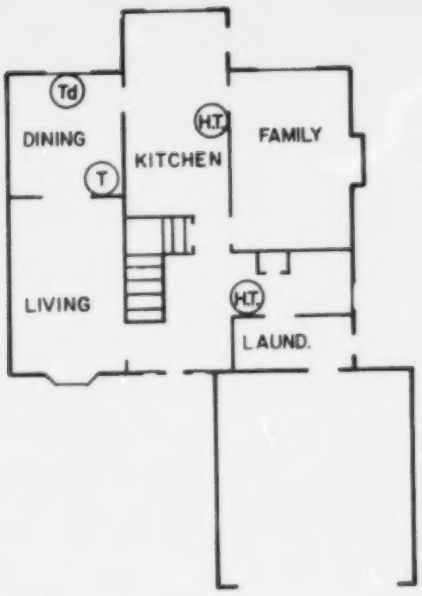
Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 1	Children: 1	

SPACE HEATING: HOTCAN vs ACTUAL

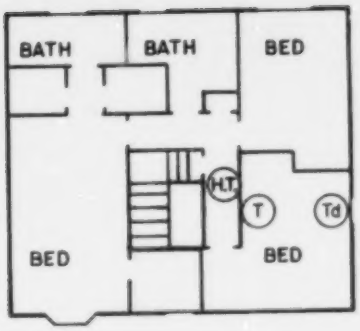


Hotcan Predictions
- Space Heating: 8,160 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

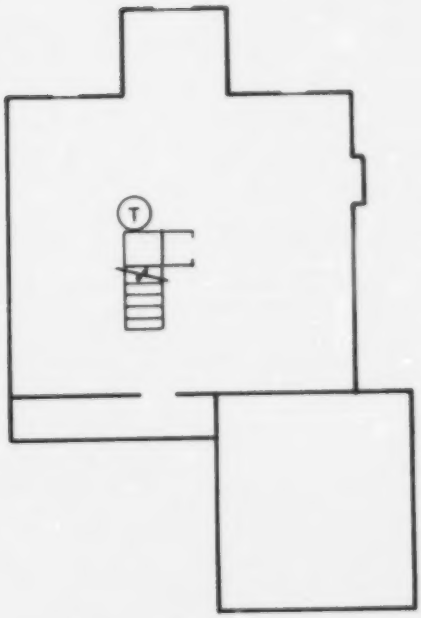
Actual (extrapolated) Space Heating: 11,024 kWh



GROUND FLOOR



SECOND FLOOR



BASEMENT

HOUSE A, FONTHILL

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

HOUSE B, FONTHILL, ONTARIO

Type of House: 2 Storey, Full basement

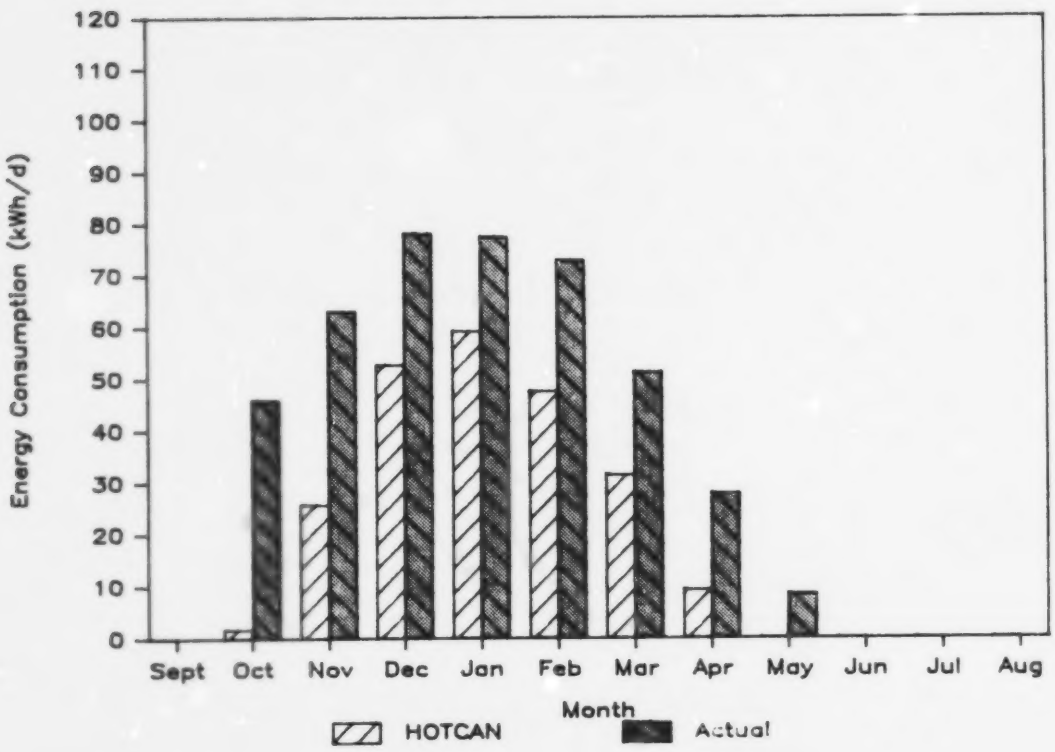
Appliances (Make & Type)
- Furnace: York - natural gas
- DHW Heater: Rheem - electric
- Fireplace(s): One

Floor Area: 215.9 m^2

Homeowner Profile

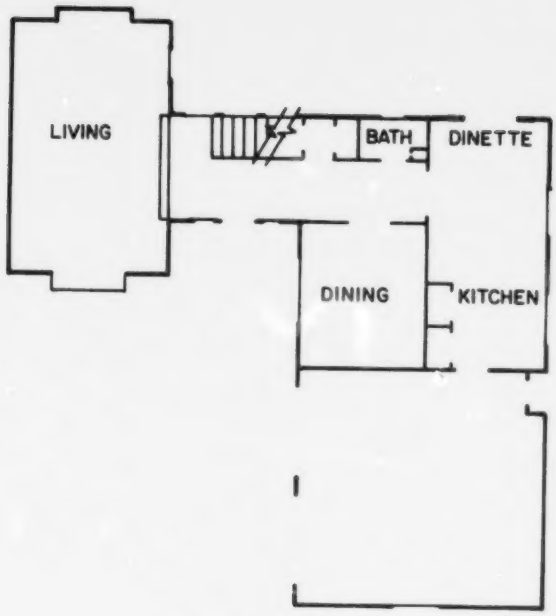
Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children:	1-after Nov 85
Number home during the day:	Adults: 0	Children:	0

SPACE HEATING: HOTCAN vs ACTUAL

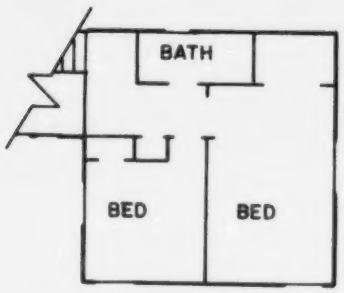


Hotcan Predictions
- Space Heating: 6,898 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 12,617 kWh

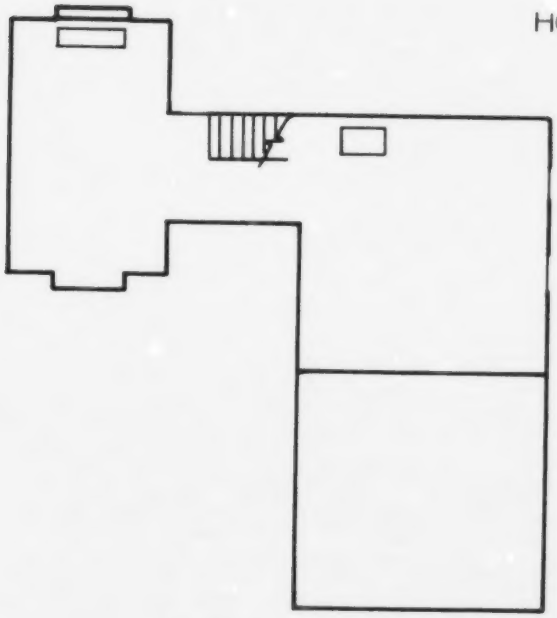


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE B, FONTHILL

HOUSE C, FONTHILL, ONTARIO

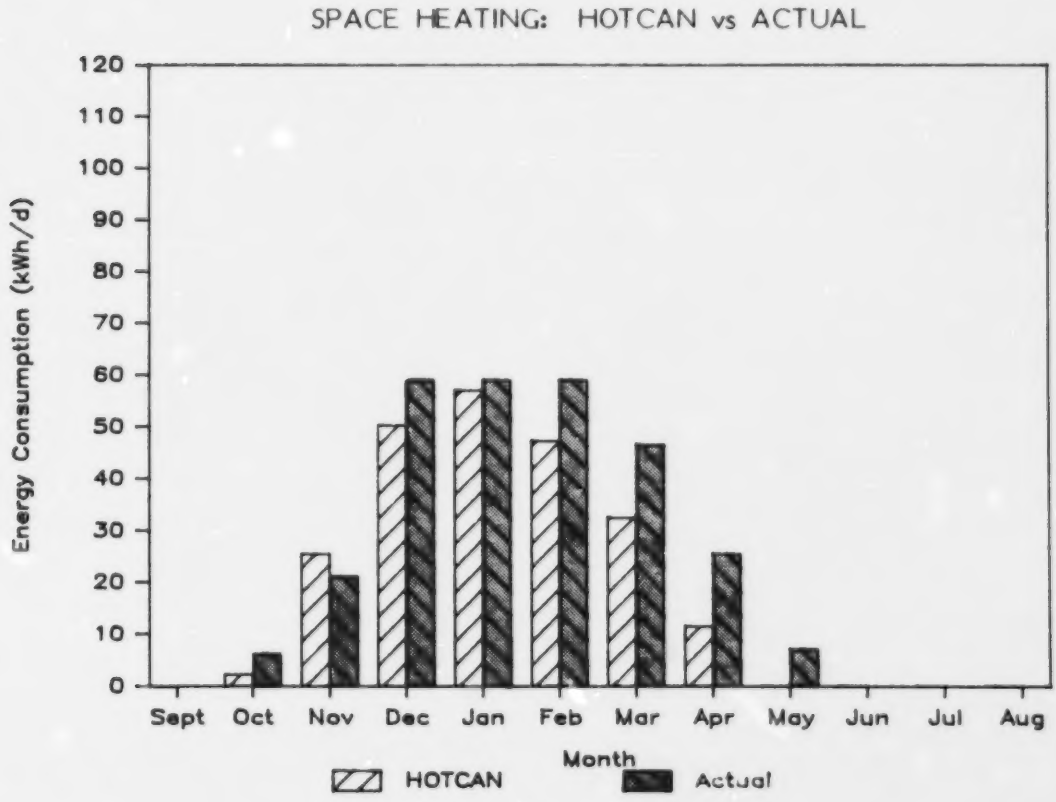
Type of House: 2 Storey, Full basement

Appliances (Make & Type)
- Furnace: Clare - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One

Floor Area: 241.9 m^2

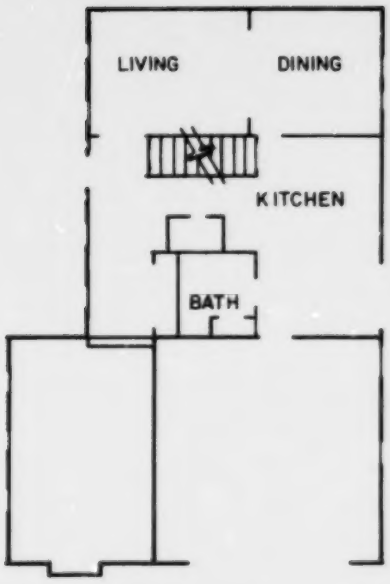
Homeowner Profile

Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 3	
Number home during the day:	Adults: 1	Children: 1	

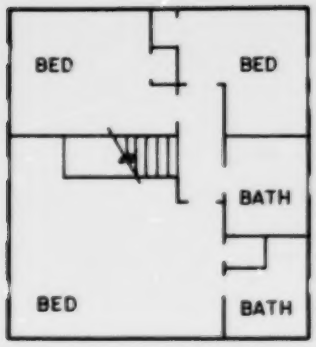


Hotcan Predictions
- Space Heating: 6,855 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 8,387 kWh

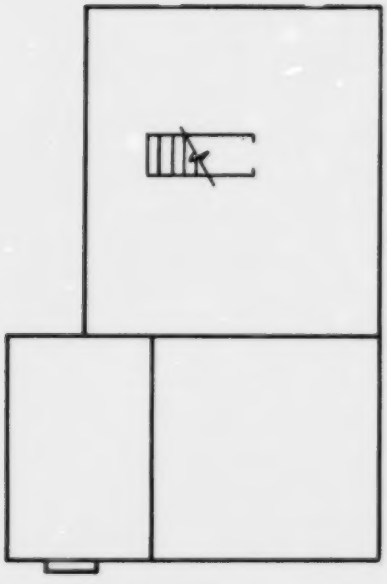


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE C, FONTHILL

HOUSE D, FONTHILL, ONTARIO

Type of House: 2 Storey, Full basement

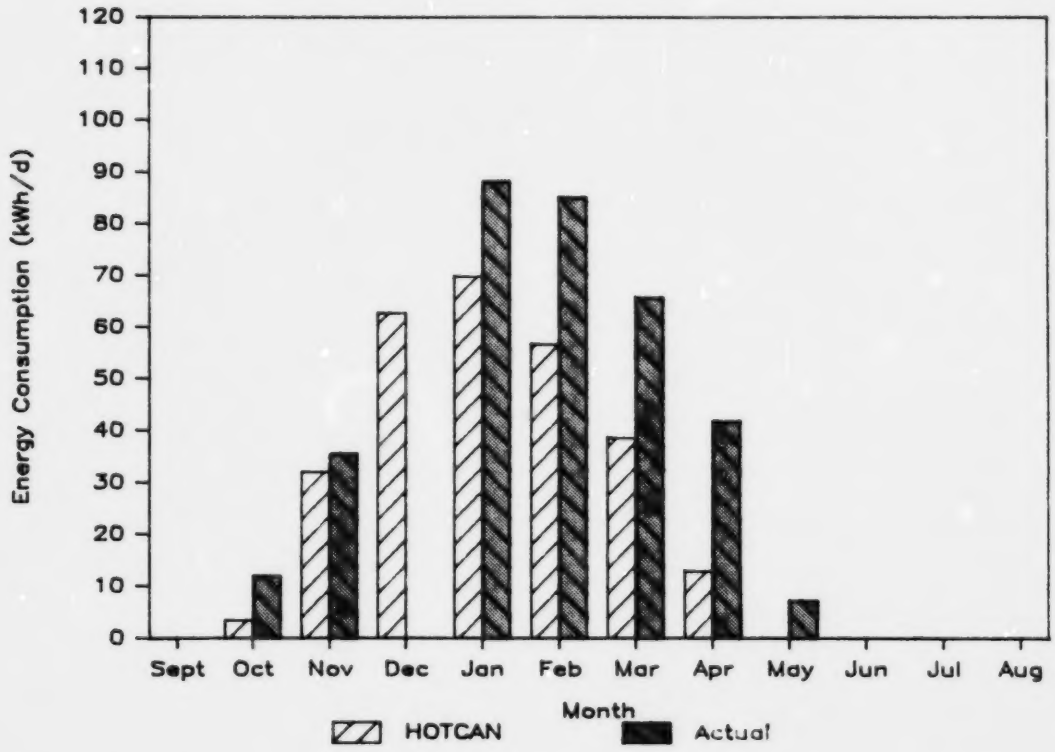
Appliances (Make & Type)
- Furnace: Clare - electric
- DHW Heater: Rheem - electric
- Fireplace(s): One

Floor Area: 282.9 m^2

Homeowner Profile

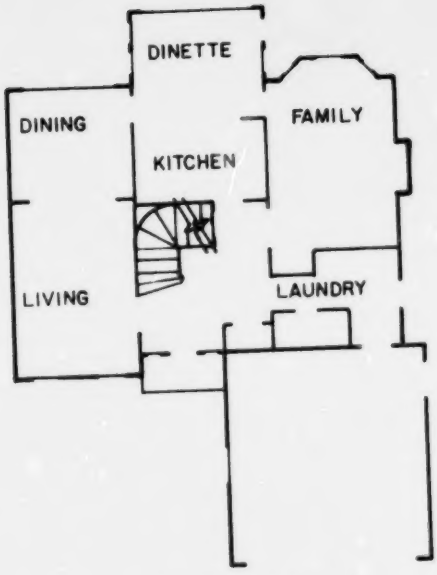
Age of owner: 31 - 45	Age of Spouse: 18 - 30		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

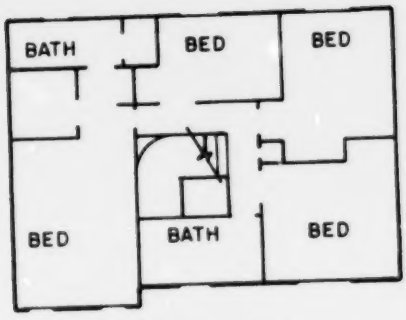


Hotcan Predictions
- Space Heating: 8,356 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 12,868 kWh

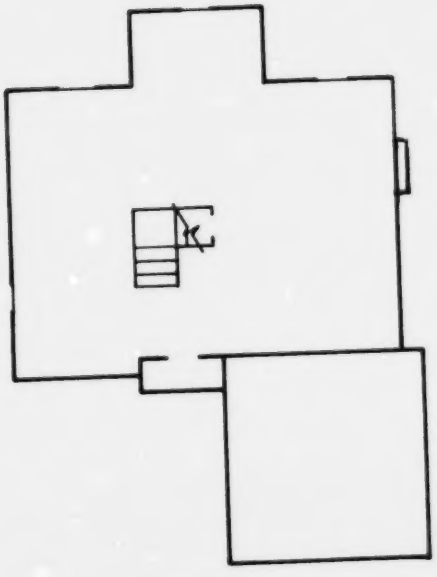


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE D, FONTHILL

HOUSE E, FONTHILL, ONTARIO

Type of House: 2 Storey - Full basement

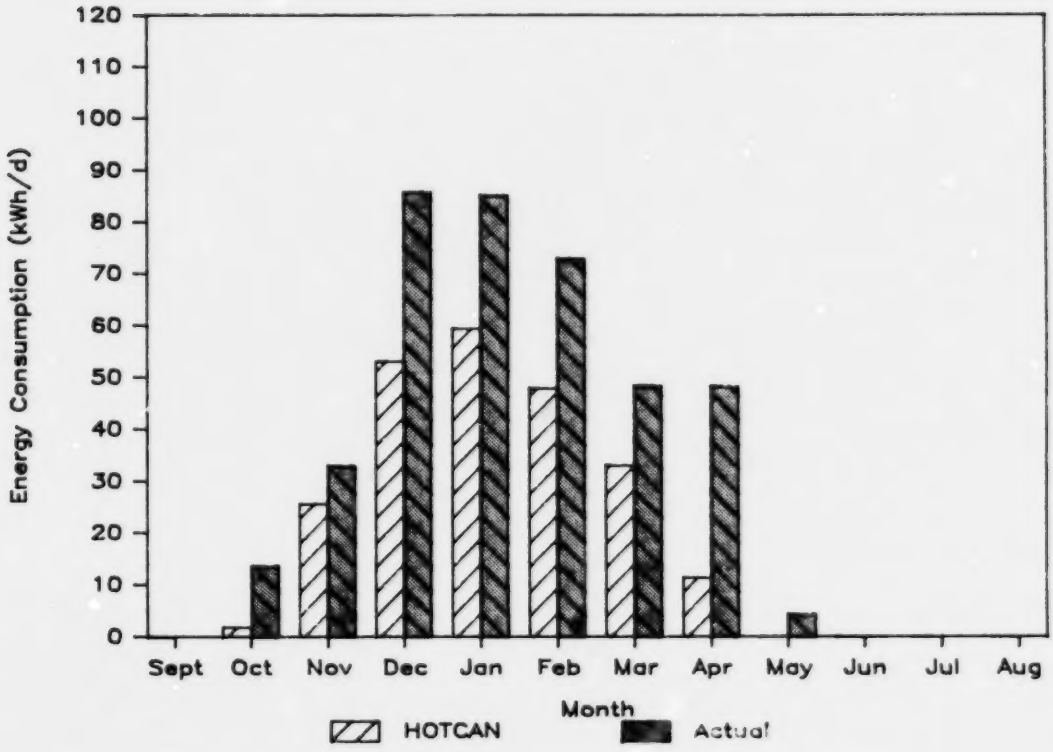
Appliances (Make & Type)
- Furnace: York - electric
- DHW Heater: Rheem - electric
- Fireplace(s): One

Floor Area: 238.9 m^2

Homeowner Profile

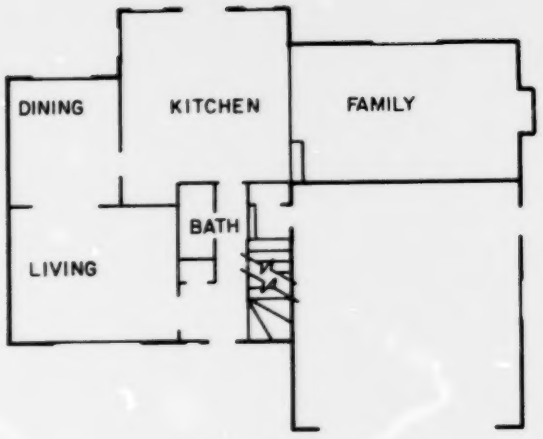
Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

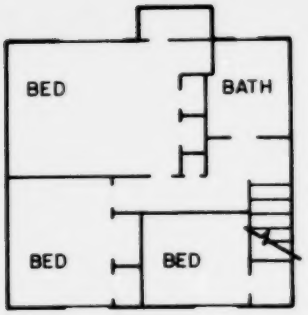


Hotcan Predictions
- Space Heating: 7,031 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 11,739 kWh

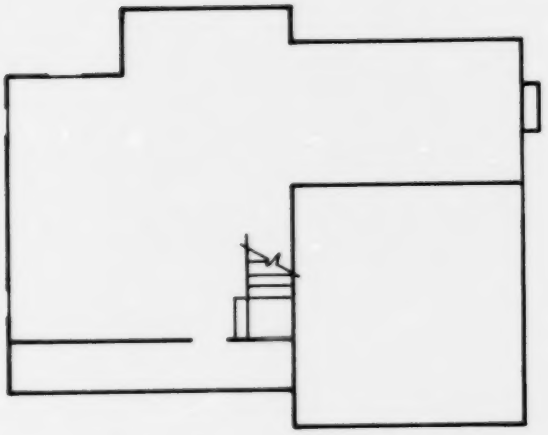


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASMENT

HOUSE E, FONTHILL

HOUSE A, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

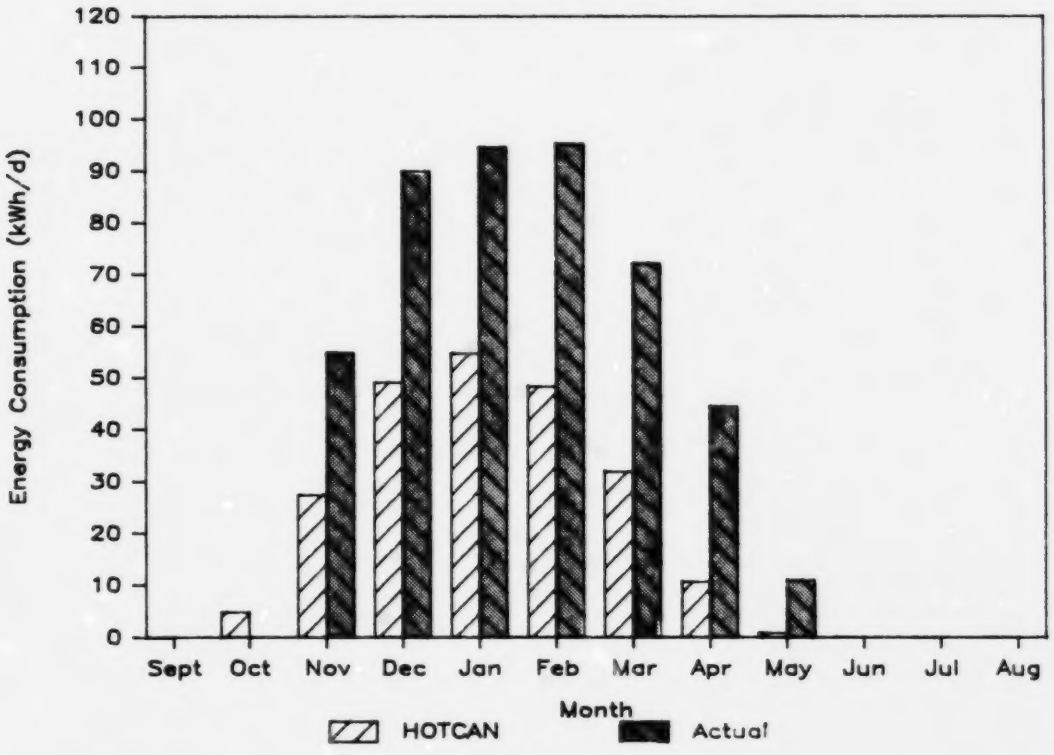
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two

Floor Area: 228.3 m^2

Homeowner Profile:

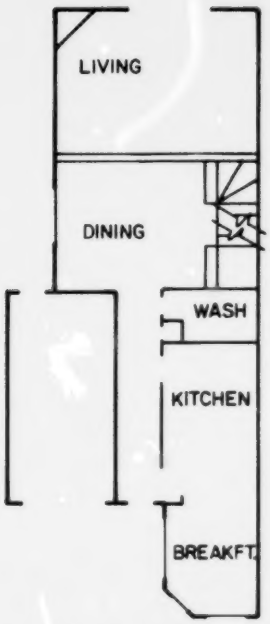
Age of owner: 31 - 45	Age of Spouse: —		
Number of occupants:	Adults: 1	Children: 0	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

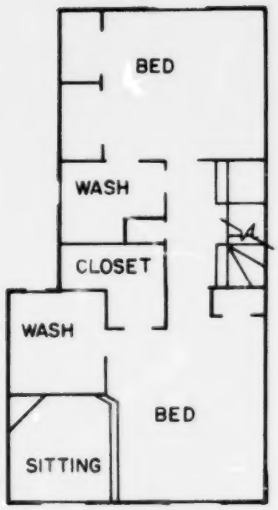


Hotcan Predictions:
- Space Heating: 6,909 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 14,291 kWh

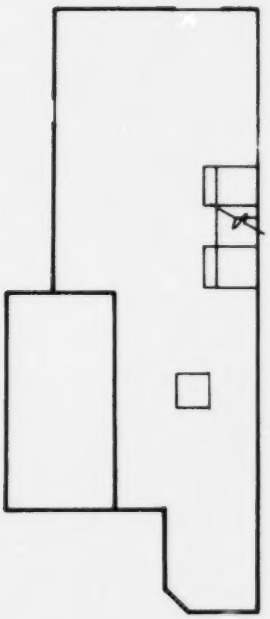


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE A, ERIN MILLS

HOUSE B, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

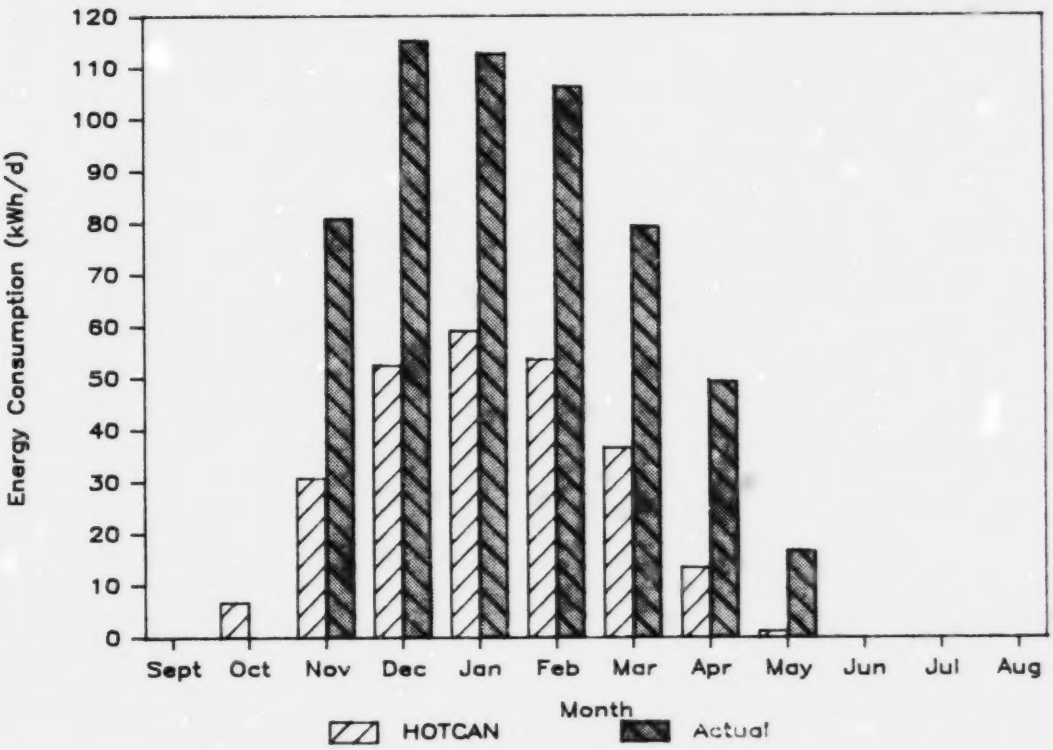
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two

Floor Area: 228.3 m^2

Homeowner Profile

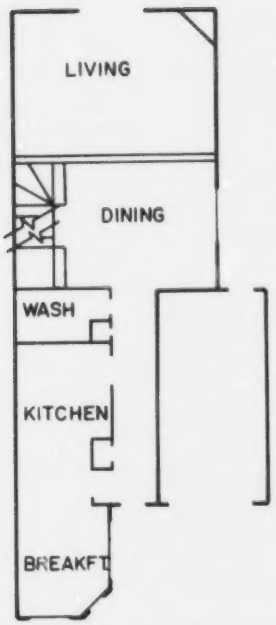
Age of owner: 31 - 45	Age of Spouse: 31 - 45		
Number of occupants:	Adults: 2	Children: 1	
Number home during the day:	Adults: 0	Children: 0	

SPACE HEATING: HOTCAN vs ACTUAL

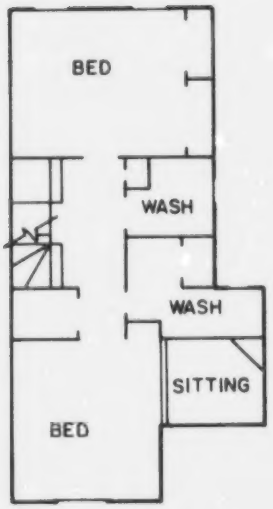


Hotcan Predictions:
- Space Heating: 7,684 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 17,430 kWh

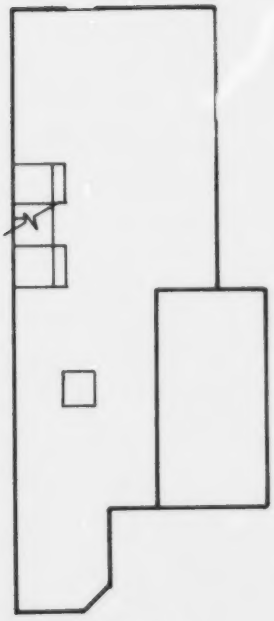


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE B, ERIN MILLS

HOUSE C, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full baseme

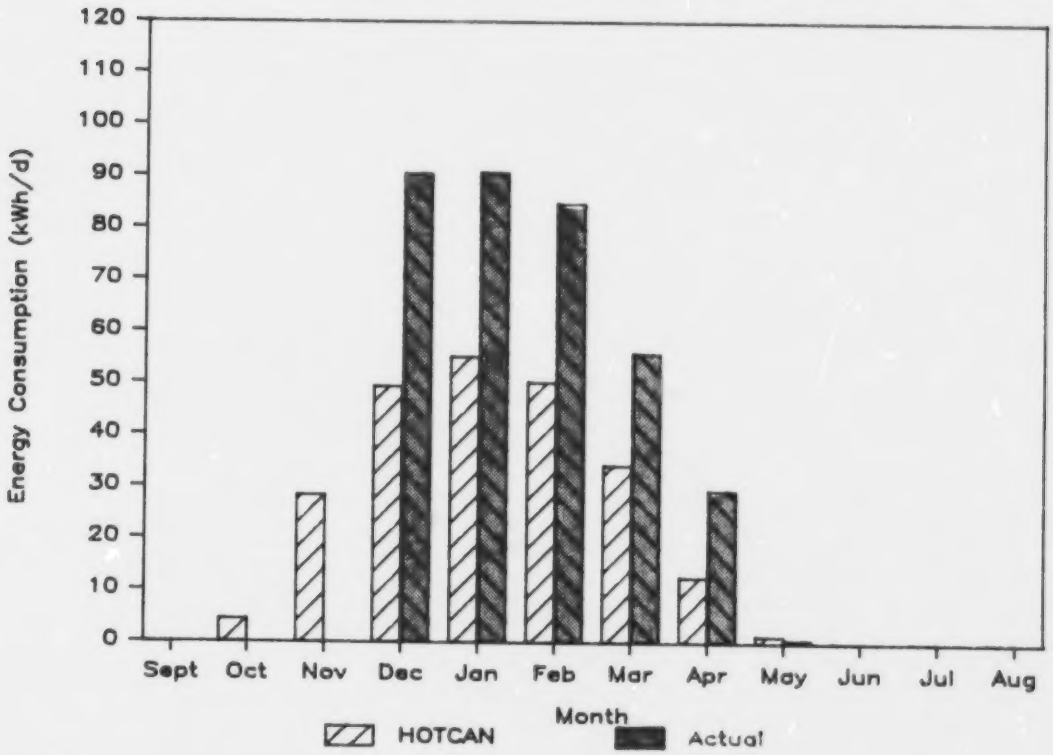
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): Two

Floor Area: 228.3 m^2

Homeowner Profile

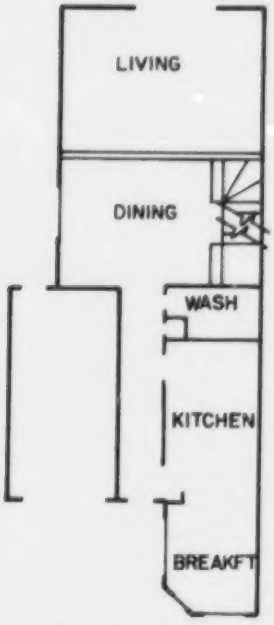
Age of owner: 31 - 45	Age of Spouse:	31 - 45	
Number of occupants:	Adults: 2	Children:	0
Number home during the day:	Adults: 0	Children:	0

SPACE HEATING: HOTCAN vs ACTUAL

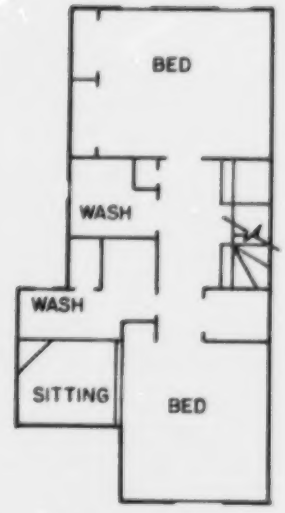


Hotcan Predictions:
- Space Heating: 7,111 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 13,027 kWh

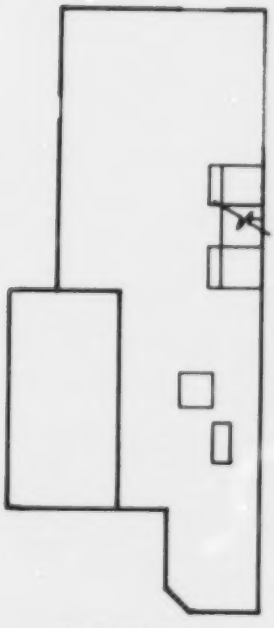


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE C, ERIN MILLS

HOUSE D, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

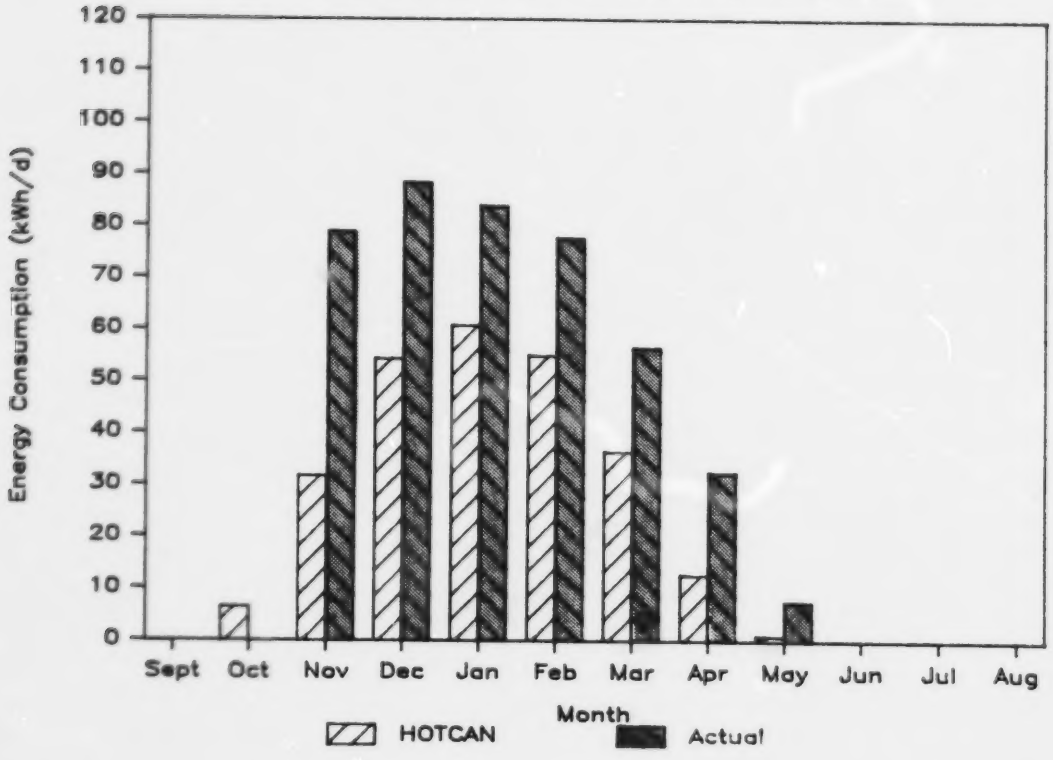
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One

Floor Area: 238.3 m^2

Homeowner Profile

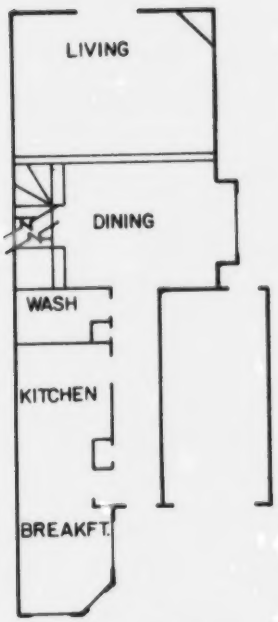
Age of owner:	31 - 45	Age of Spouse:	
Number of occupants:		Adults: 1	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL

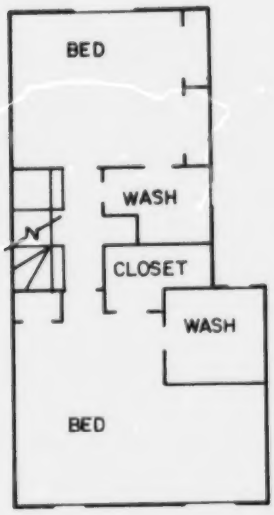


Hotcan Predictions:
- Space Heating: 7,810 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 13,210 kWh

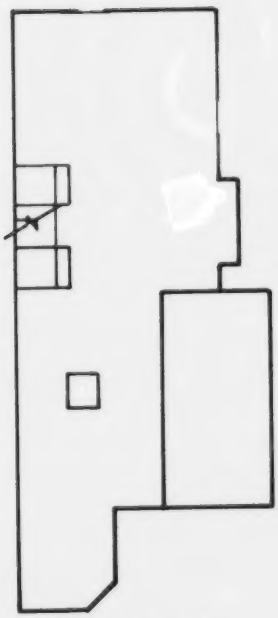


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE D, ERIN MILLS

HOUSE E, ERIN MILLS, ONTARIO

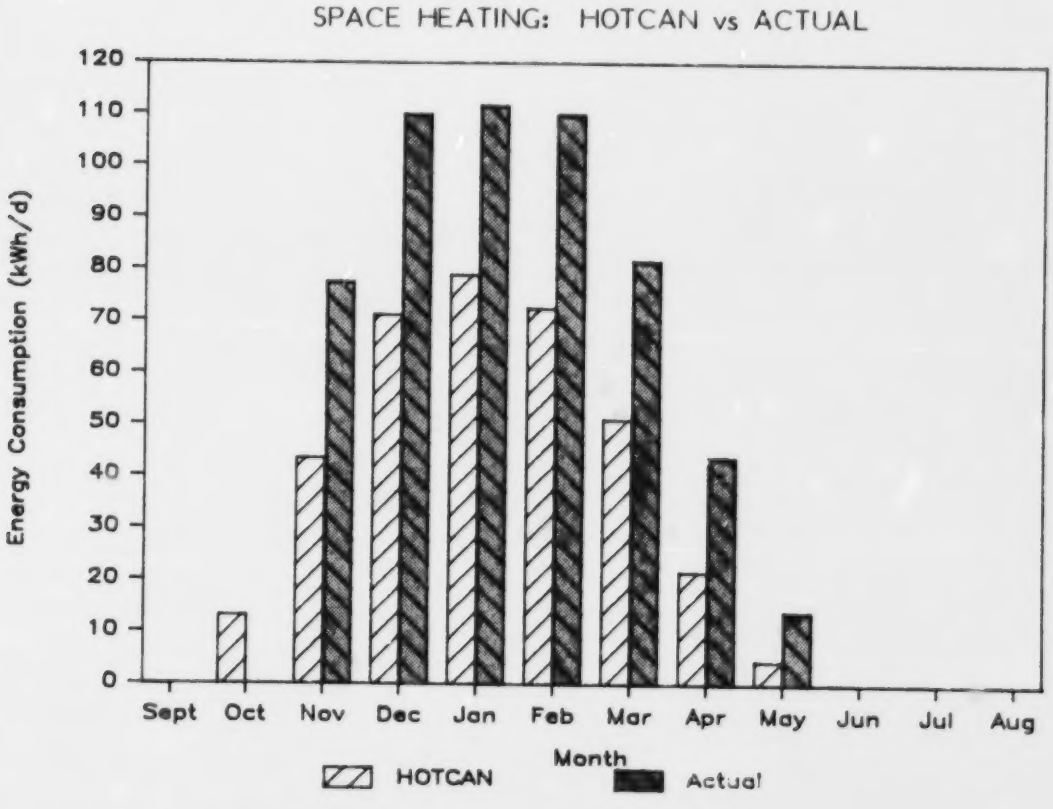
Type of House: Attached Row House - Unfinished full basement

Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One

Floor Area: 249.6 m^2

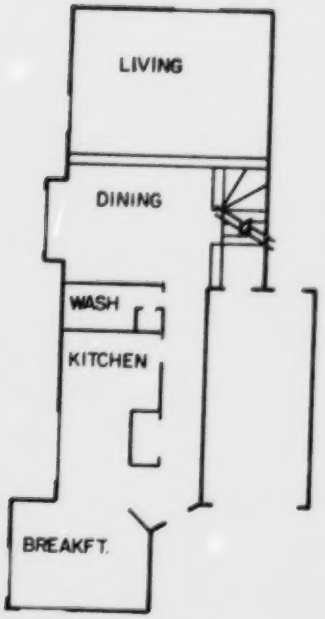
Homeowner Profile

Age of owner:	46 - 60	Age of Spouse:	46 - 60
Number of occupants:		Adults: 5	Children: 0
Number home during the day:		Adults: 0	Children: 0

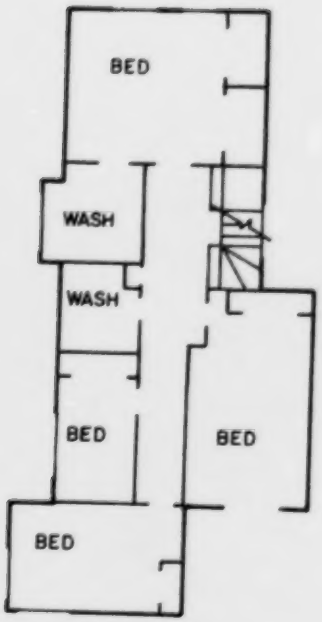


Hotcan Predictions:
- Space Heating: 10,775 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 17,217 kWh



GROUND FLOOR



SECOND FLOOR

0 5 METRES

BASEMENT

HOUSE E, ERIN MILLS

HOUSE F, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

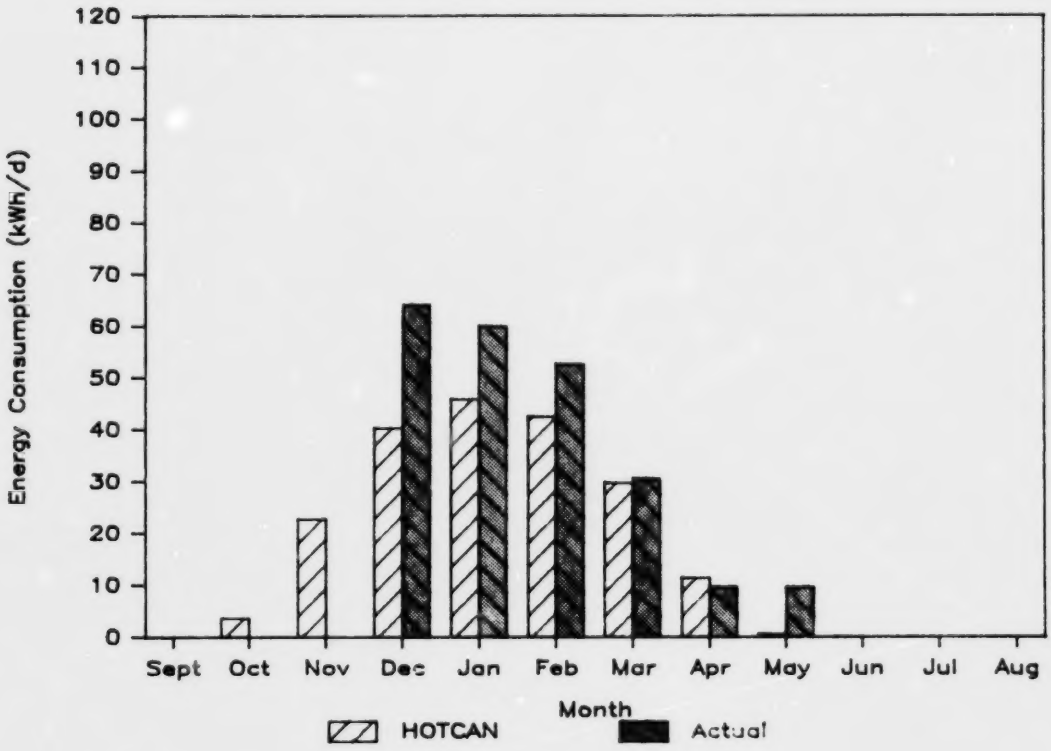
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One

Floor Area: 215.4 m^2

Homeowner Profile

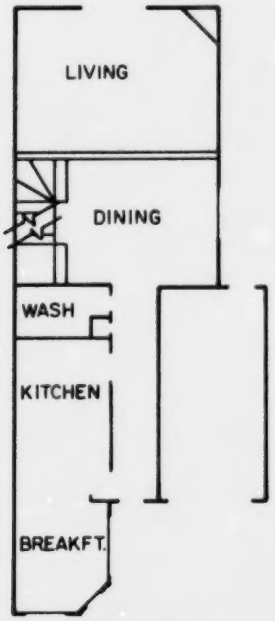
Age of owner:	46 - 60	Age of Spouse:	18 - 30
Number of occupants:		Adults: 2	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL

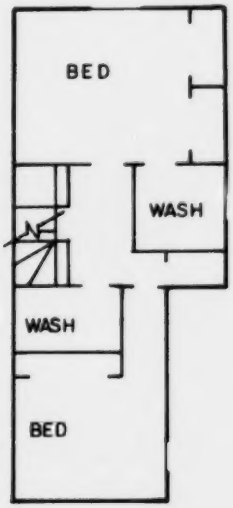


Hotcan Predictions:
- Space Heating: 5,952 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 7,950 kWh

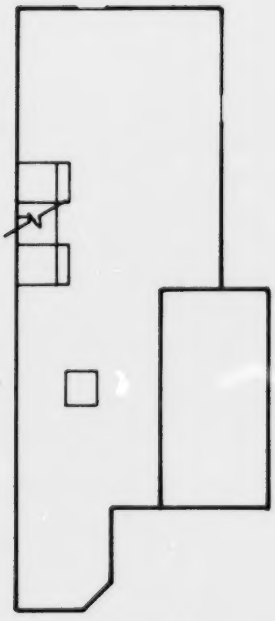


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE F, ERIN MILLS

HOUSE G, ERIN MILLS, ONTARIO

Type of House: Attached Row House - Unfinished full basement

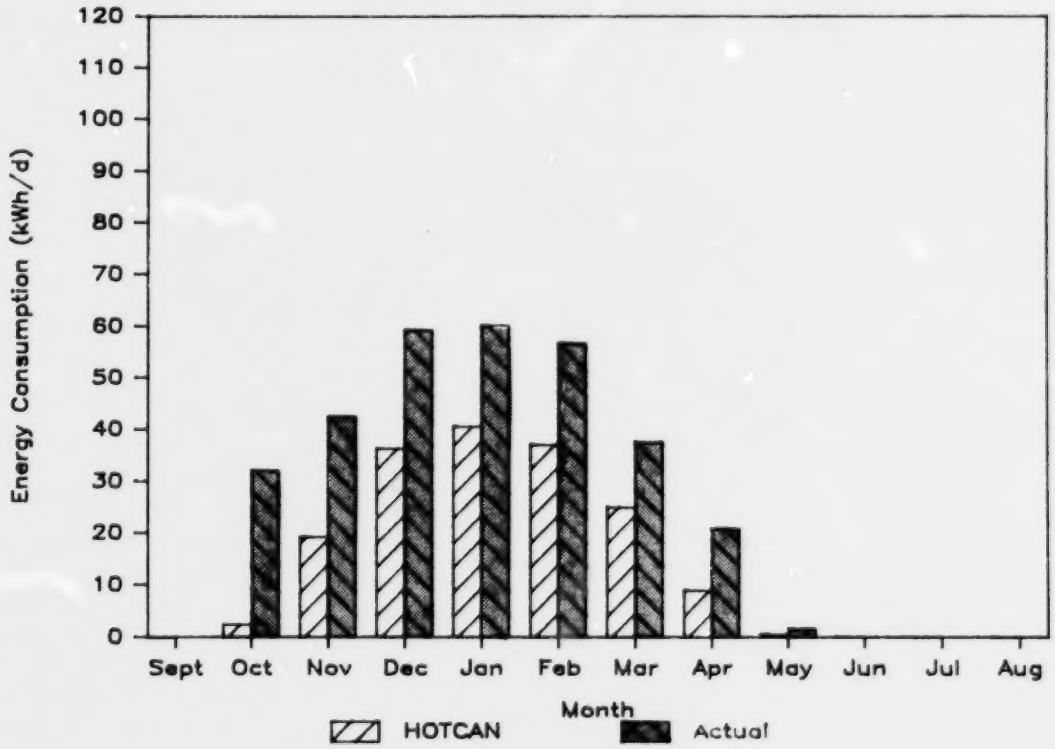
Appliances (Make & Type):
- Furnace: Clare Bros. - electric
- DHW Heater: G.S.W. - electric
- Fireplace(s): One

Floor Area: 215.4 m^2

Homeowner Profile

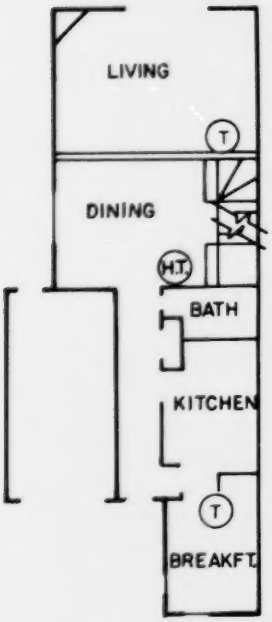
Age of owner:	18 - 30	Age of Spouse:	
Number of occupants:		Adults: 1	Children: 0
Number home during the day:		Adults: 0	Children: 0

SPACE HEATING: HOTCAN vs ACTUAL

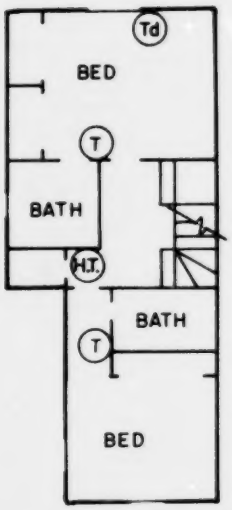


Hotcan Predictions:
- Space Heating: 5,154 kWh
- DHW: 5,110 kWh
- Other: 5,110 kWh

Actual (extrapolated) Space Heating: 9,401 kWh

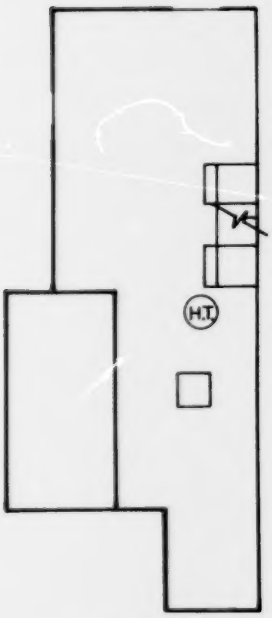


GROUND FLOOR



SECOND FLOOR

0 5 METRES



BASEMENT

HOUSE G, ERIN MILLS

T - Wall Mounted Temperature Sensor
Td - Duct Mounted Temperature Sensor
HT - Wall Mounted Humidity/Temperature Sensor

APPENDIX B

THERMOGRAPHIC SCAN RESULTS

APPENDIX B THERMOGRAPHIC SCAN RESULTS

The following thermographic scan results briefly describe photographs that are referred to in each paragraph below. Each page of photographs contains three photographs which were taken while the houses were not depressurized. Photograph A is a black and white reproduction of the colour reference picture showing where the actual thermogram was taken in the house. Photograph B is a black and white reproduction of a colour thermogram with a temperature line reference through the middle of the thermogram. The coloured thermogram shows various coloured patterns representing the apparent temperature distribution over the surface area referred to in the accompanying reference picture. Photograph C is a black and white reproduction of a coloured line scan showing a $1^{o}C$ temperature difference between each horizontal line. The line scan shows the actual degree difference across the horizontal reference line in the accompanying thermogram.

For example, Figure B.1.a is a representative picture of the step leading into the sunken living-room in all houses in Erin Mills. Figure B.1.b is the accompanying thermogram showing a concentration of coloured patterns at the step and baseboard area. Figure B.1.c is a line scan taken through the step area which verifies a temperature drop of $3^{o}C$ at the step. These pictures reveal that the increased construction junctions at the step area are difficult to seal and keep the cold out. This problem was typical of all Erin Mills houses.

Two of the most interesting thermograms taken in the Erin Mills development are the outside thermogram, Figure B.2.b, and the attic thermogram, Figure B.3.b. These thermograms are representative of all the units and indicate the heat loss through thermal bridging through the outside facial stone and the adjoining common concrete block walls. The facial stone fits on top of the foundation wall supporting the brick veneer. Thermal bridging is a common problem in brick veneer houses with basement walls insulated on the exterior, as in Erin Mills. In Figure B.3.c, the line scan through the common concrete block wall shows a temperature difference of $3^{o}C$ along the entire length of the wall and, in Figure B.2.c, the line scan of the front facial stone shows a temperature difference of $2^{o}C$.

One of the more useful thermographic observations was the comparison of the sealing of fireplaces in Erin Mills and elsewhere. Figure B.4 includes a thermogram of the fireplace at House D in Fonthill. This fireplace was particularly well sealed and shows that the builder paid particular

attention to this detail. The accompanying line scan, Figure B.4.c shows a temperature difference of 2°C to 3°C. However, the fireplace in House G in Erin Mills, Figure B.5, is significantly colder with a temperature difference of 7.5°C shown by the line scan, Figure B.5.c. This was typical of all Erin Mills fireplaces.

Figures B.6 through B.12 represent typical air leakage places in all houses, in all locations. These include Figure B.6.a, which is a typical living-room wall plug outlet installation. The accompanying thermogram, Figure B.6.b, and line scan, Figure B.6.c, indicate that there is some thermal bridging and air infiltration around this outlet. This illustration was typical of most electrical service entries. Other problem areas were: improperly sealed or very cold attic hatches, as seen in Figure B.7.b; air leakage and thermal bridging in ceiling/wall joints, as seen in Figure B.8.b; and air infiltration underneath doors and around the bottom of side lights as seen in Figure B.9.b.

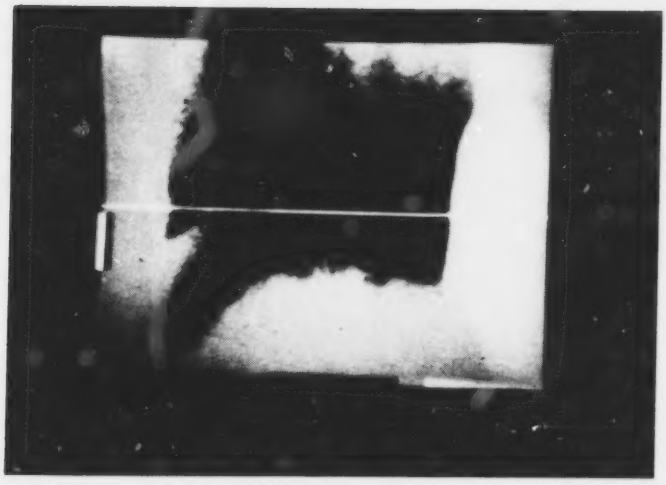
Figure B.10.a is a picture of the bottom corner of a sliding door. The accompanying thermogram, Figure B.10.b, illustrates the air infiltration around the lower corner. This infiltration is typical of all sliding doors in all locations.

Figure B.11.a illustrates the intake (or exhaust) duct to the heat recovery ventilator. In the accompanying thermogram, Figure B.11.b, the thermal bridging and air infiltration around the duct become quite apparent. Improper sealing and insulating of the HRV duct was the case in all of the houses monitored. The line scan for this thermogram, Figure B.11.c, indicates a 9.5°C temperature drop across the HRV duct.

Figure B.12.a illustrates the insulation of header spaces with Styrofoam SM and caulking rather than batt insulation. Here, the thermogram, Figure B.12.b, illustrates that totally sealing the styrofoam in place is quite difficult and air infiltrates through the crack that was missed by the caulking operation.

A

B



C

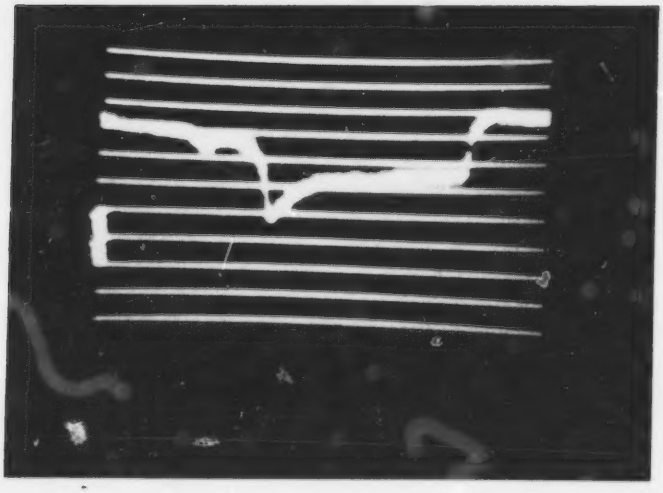


FIGURE B.1
Erin Mills:
Sunken Living Room

A

B

C

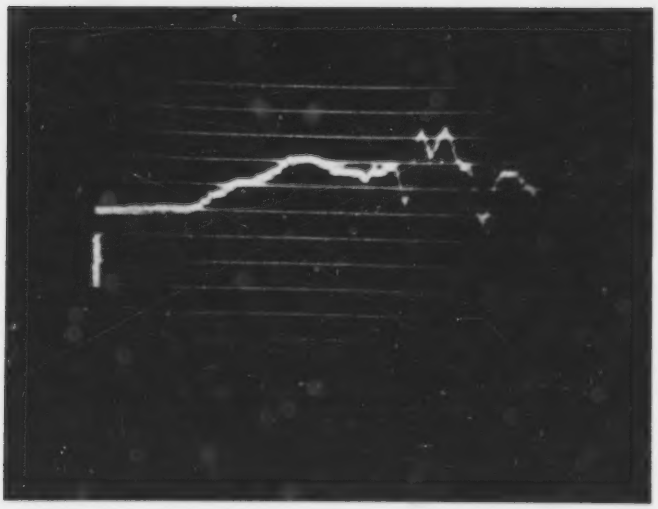


FIGURE B.2
Erin Mills:
Outside Facial
Stone

A

B

C

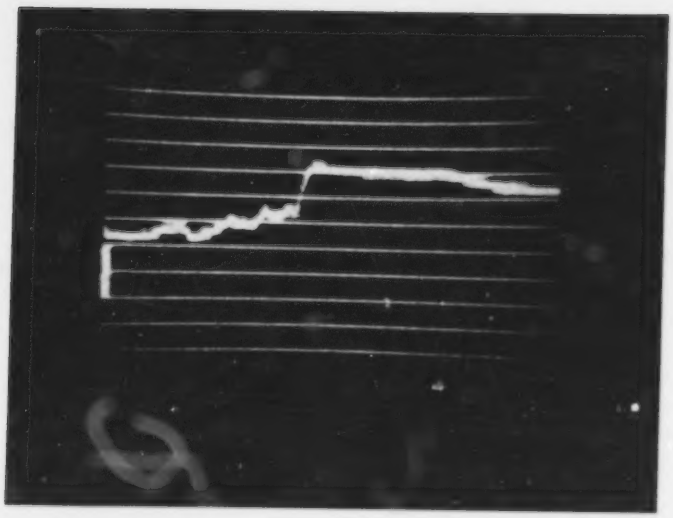
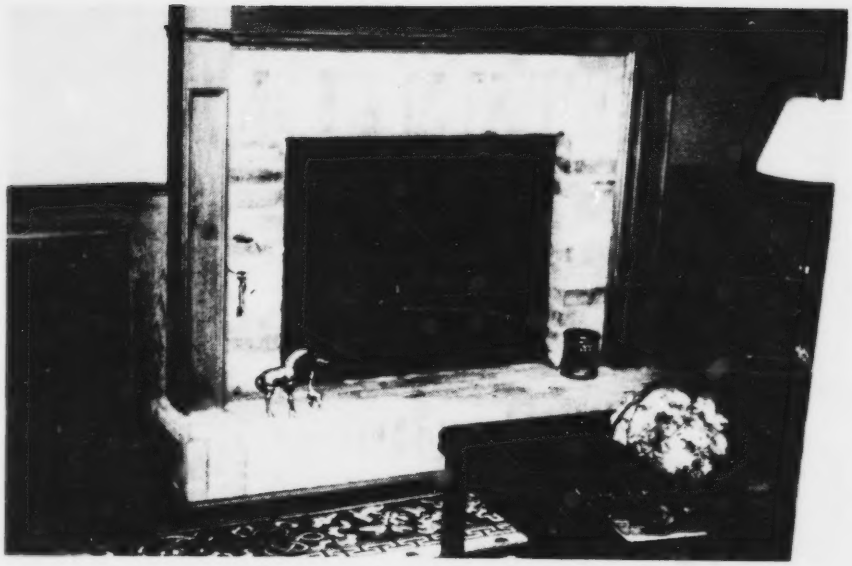
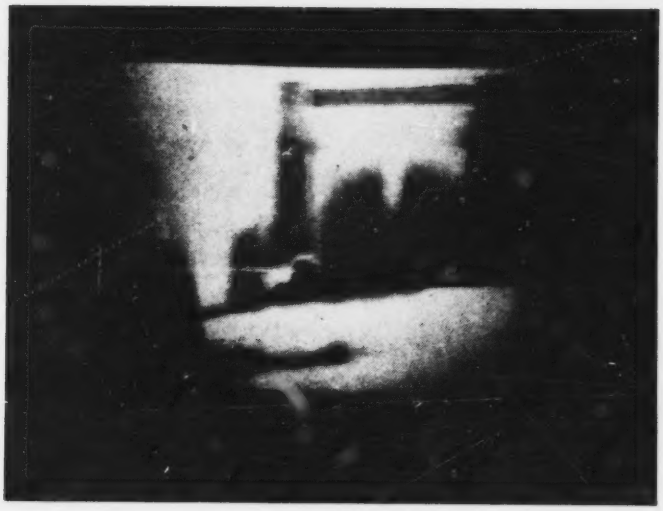


FIGURE B.3
Erin Mills:
Attic

A



B



C

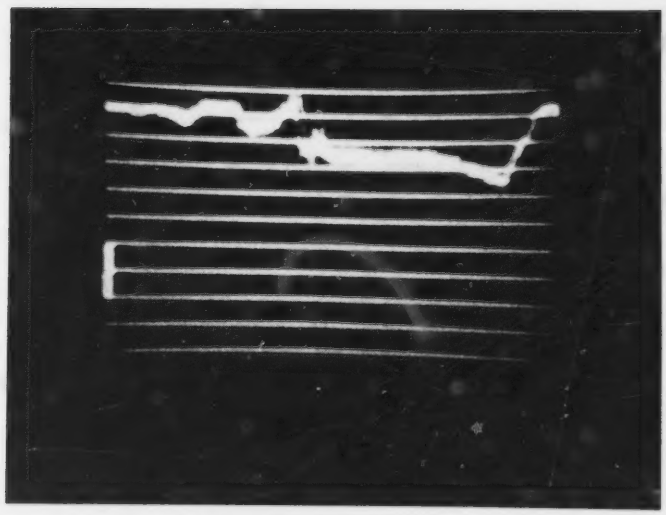
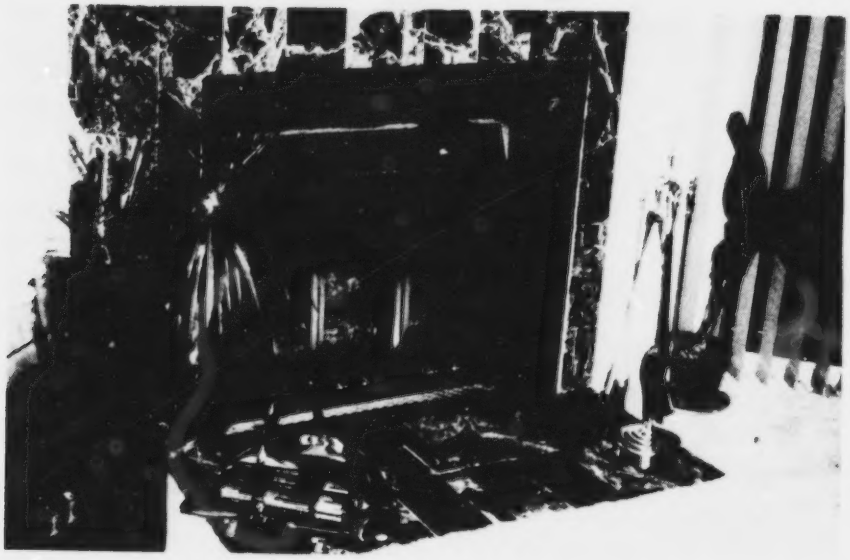
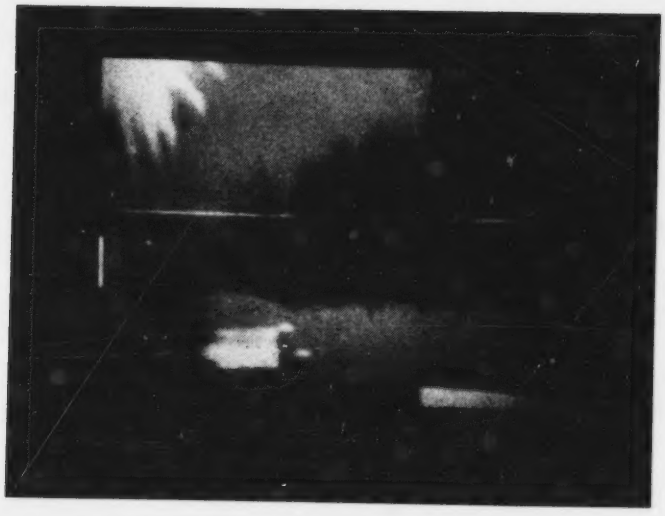


FIGURE B.4
Fonthill:
Fireplace

A



B



C

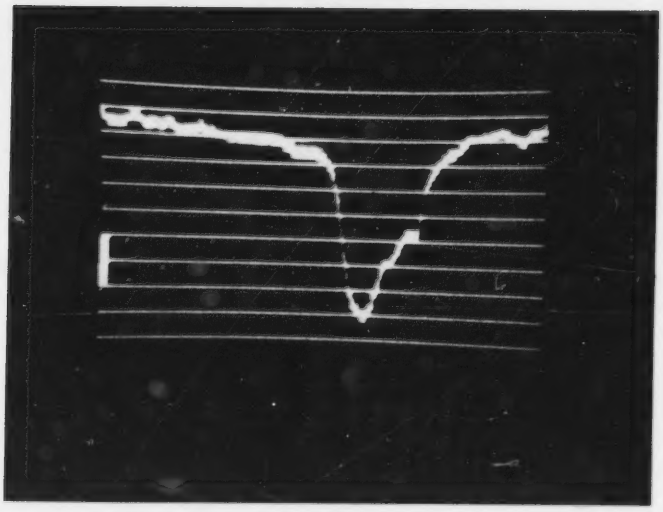
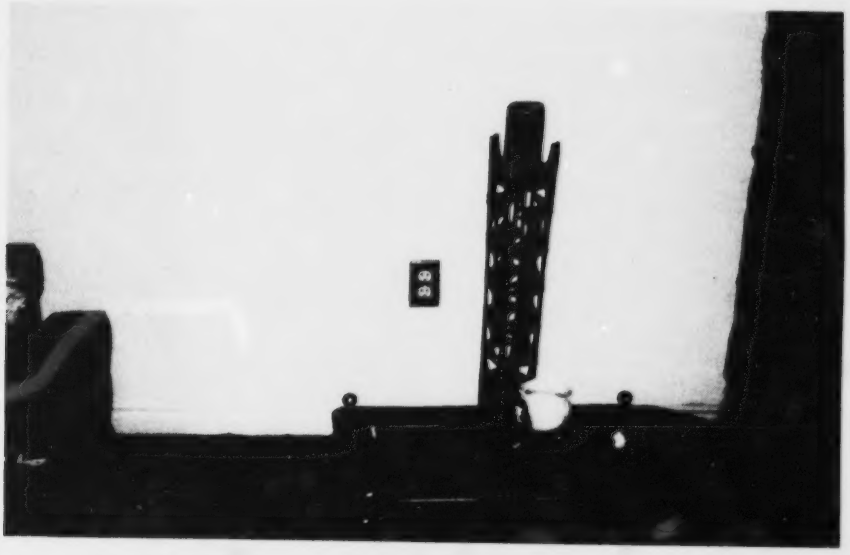
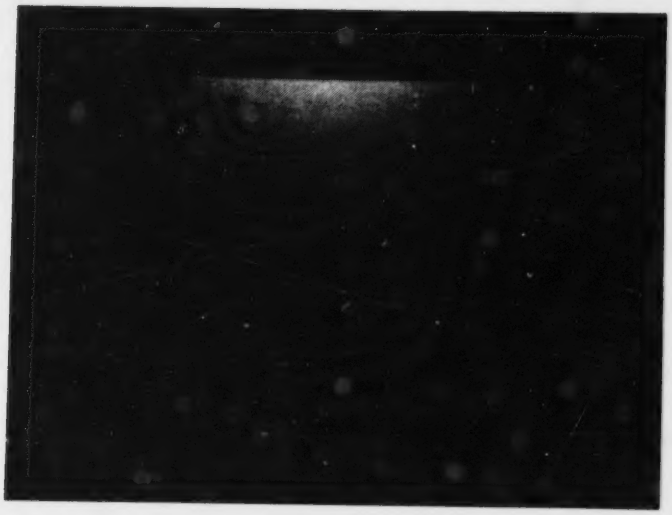


FIGURE B.5
Erin Mills:
Fireplace

A



B



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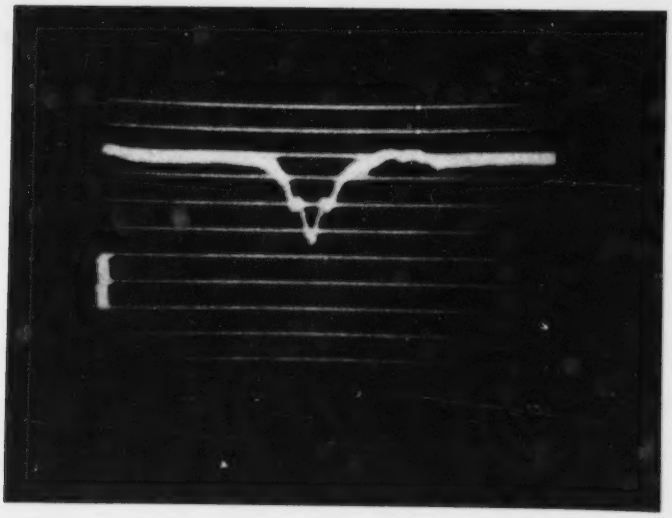
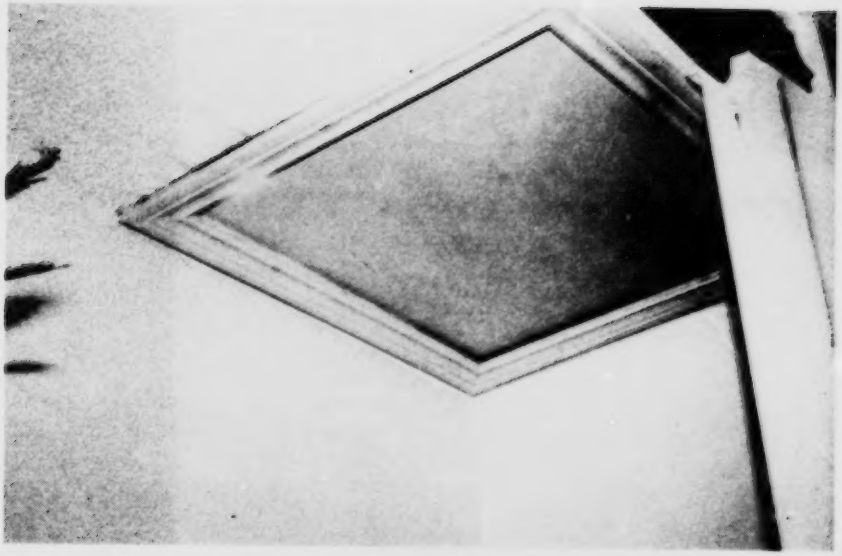
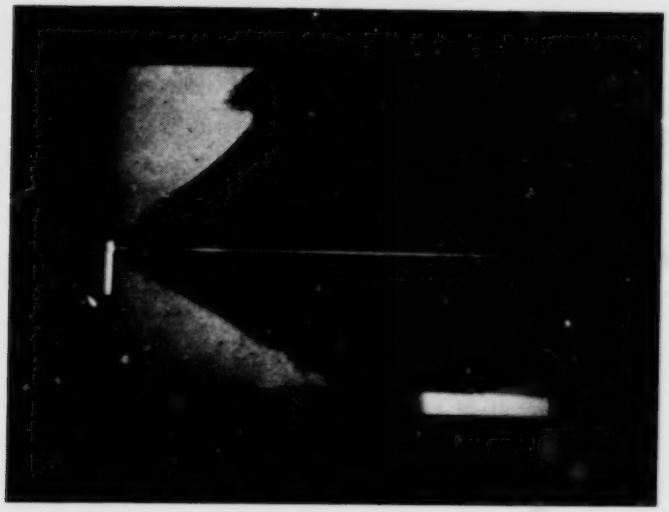


FIGURE B.6
Typical Wall Plug

A



B



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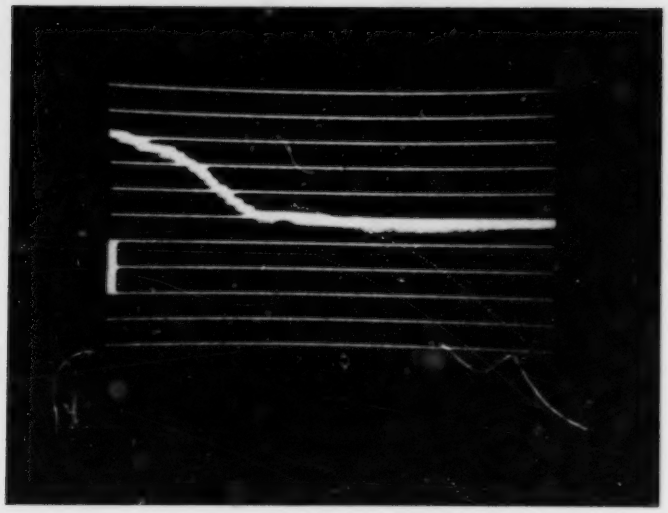
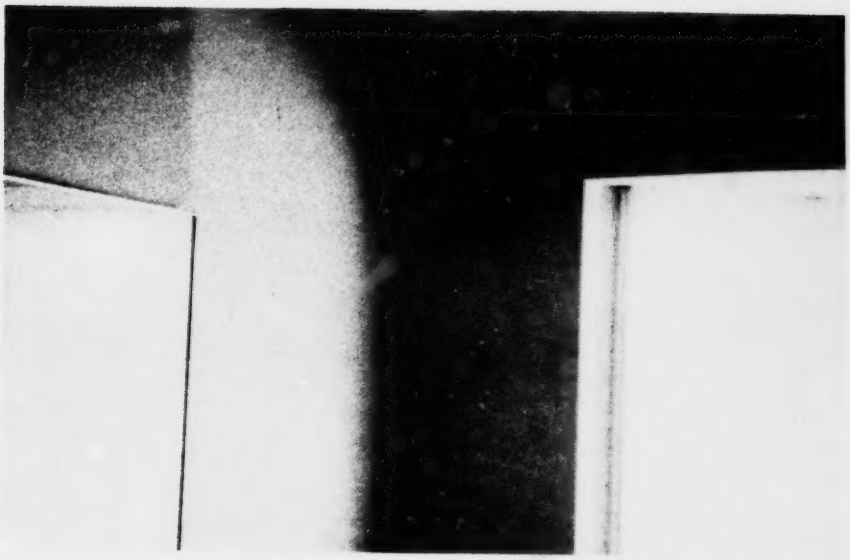


FIGURE B.7
Typical Attic
Hatch

A



B

C

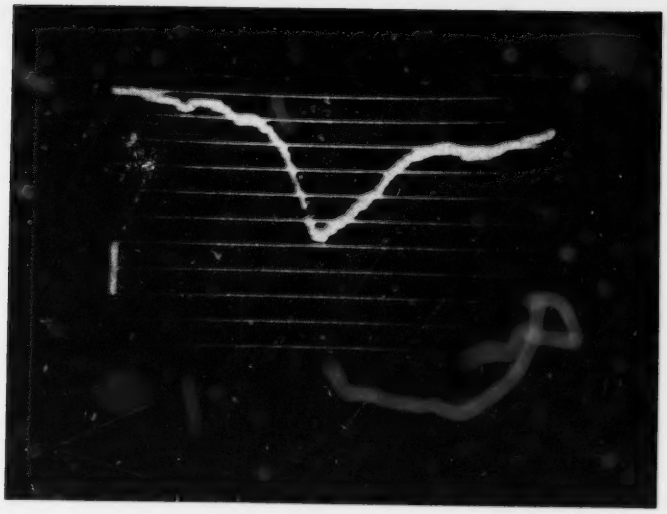


FIGURE B.8
Typical Ceiling/
Wall Joint

A

B

C

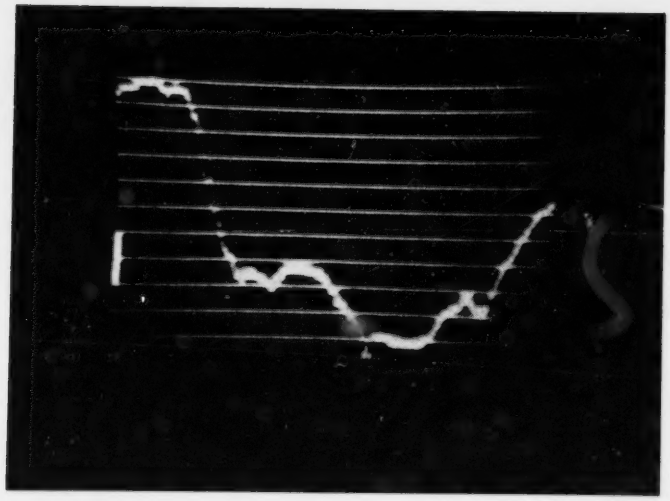
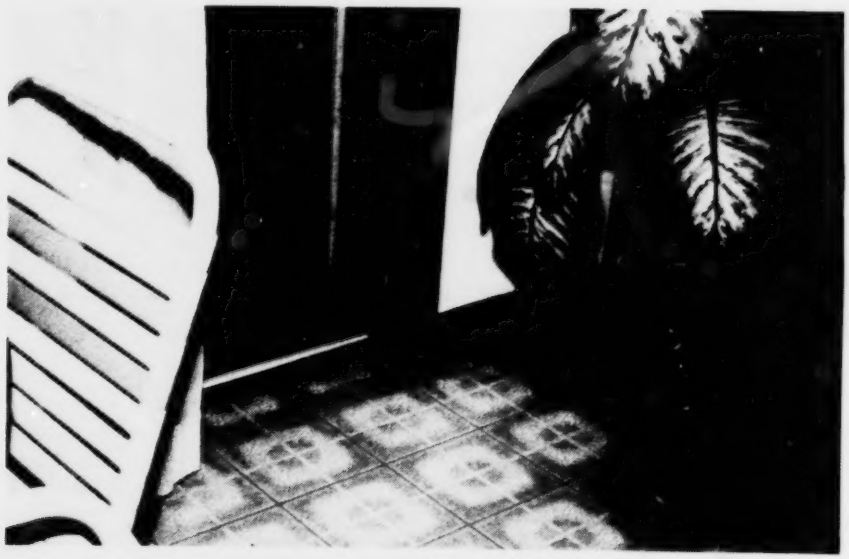


FIGURE B.9
Typical Door
and Side Light

A



B

C

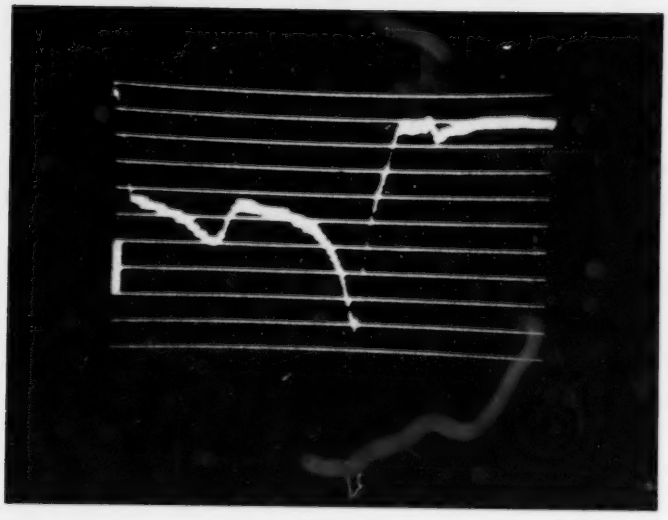


FIGURE B.10
Typical Sliding
Door

A

B

C

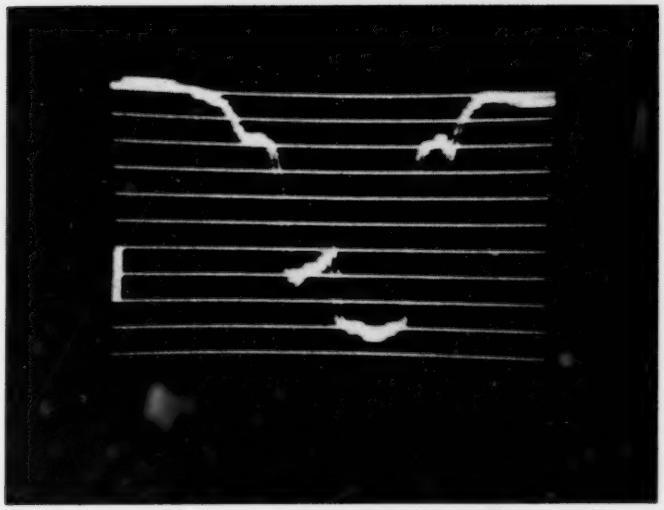
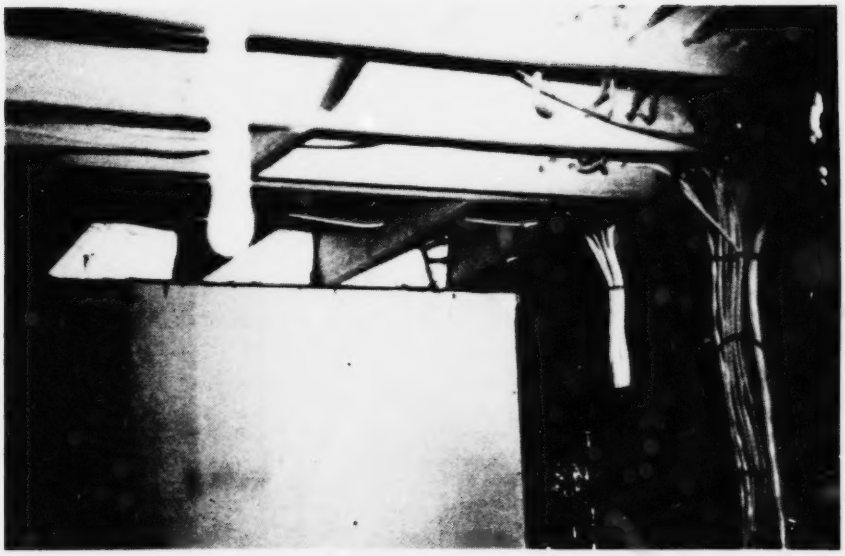


FIGURE B.11
Typical HRV
Ducting

A



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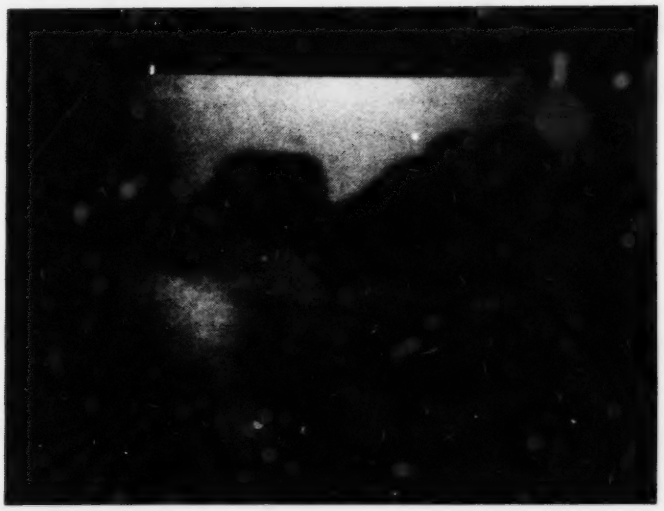


C

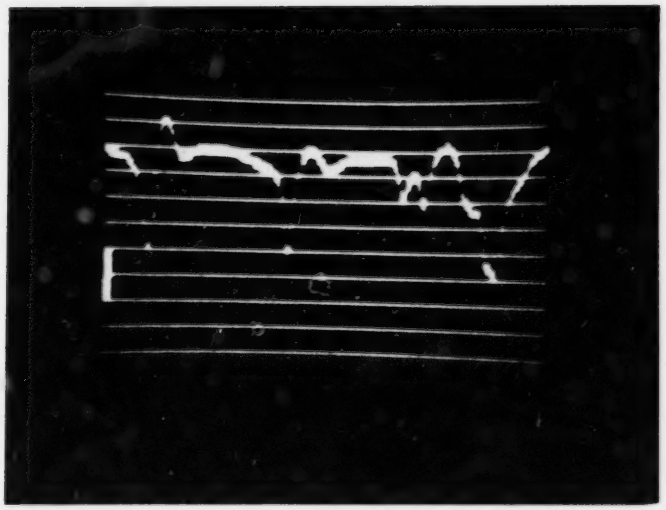
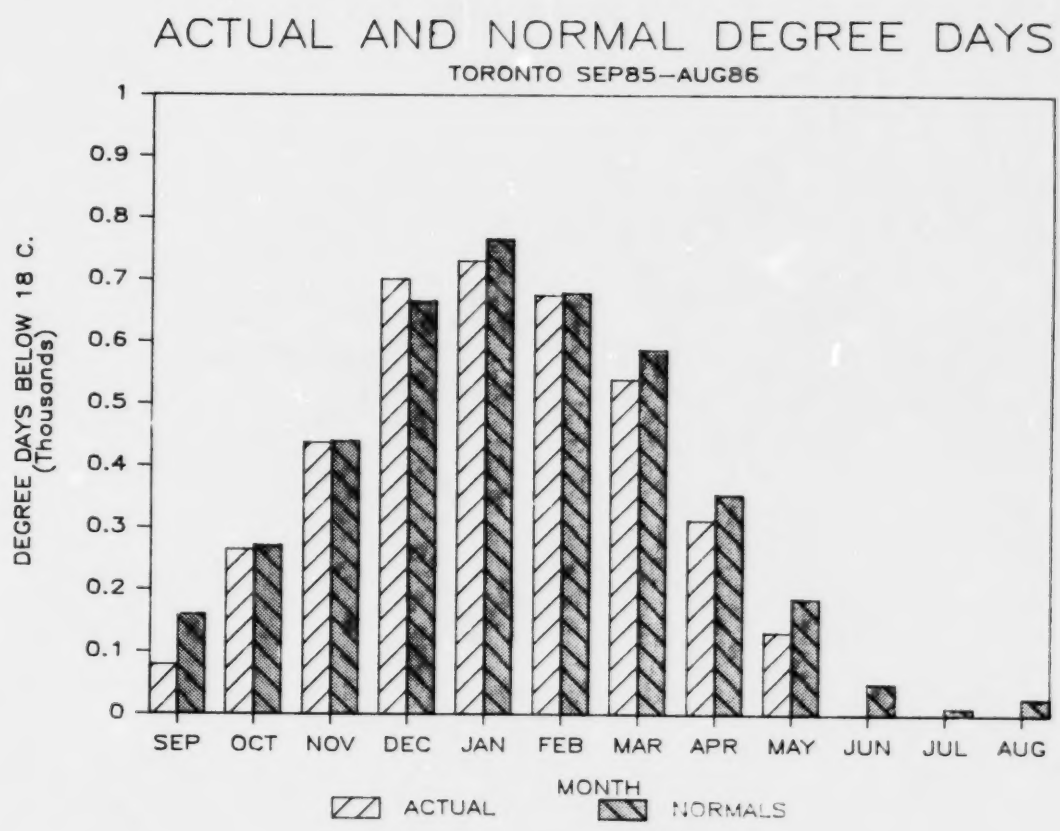
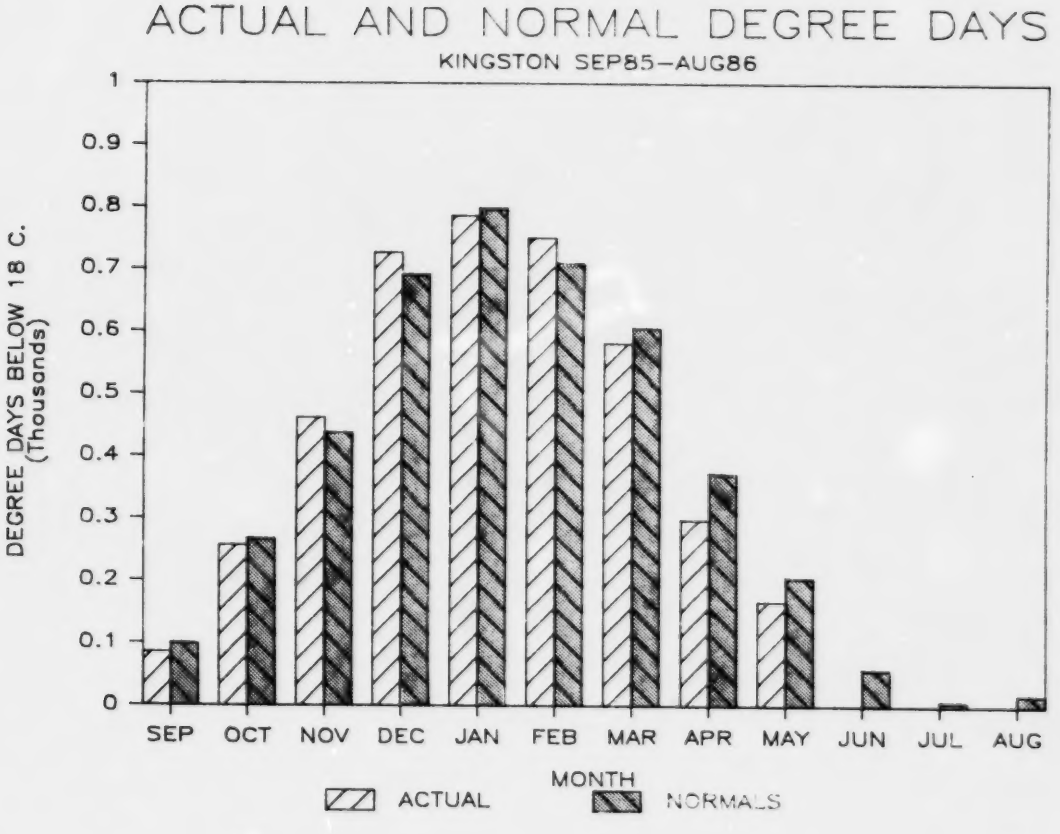


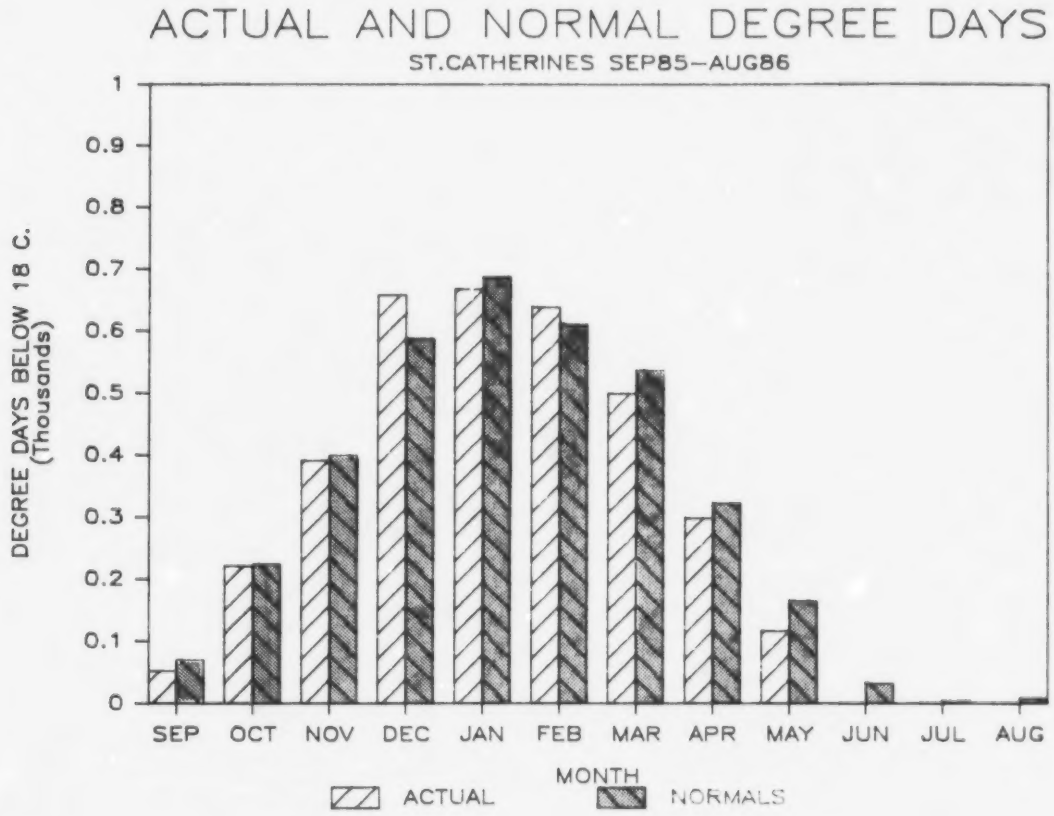
FIGURE B.12
Styrofoam SM
Insulation in
Header Space

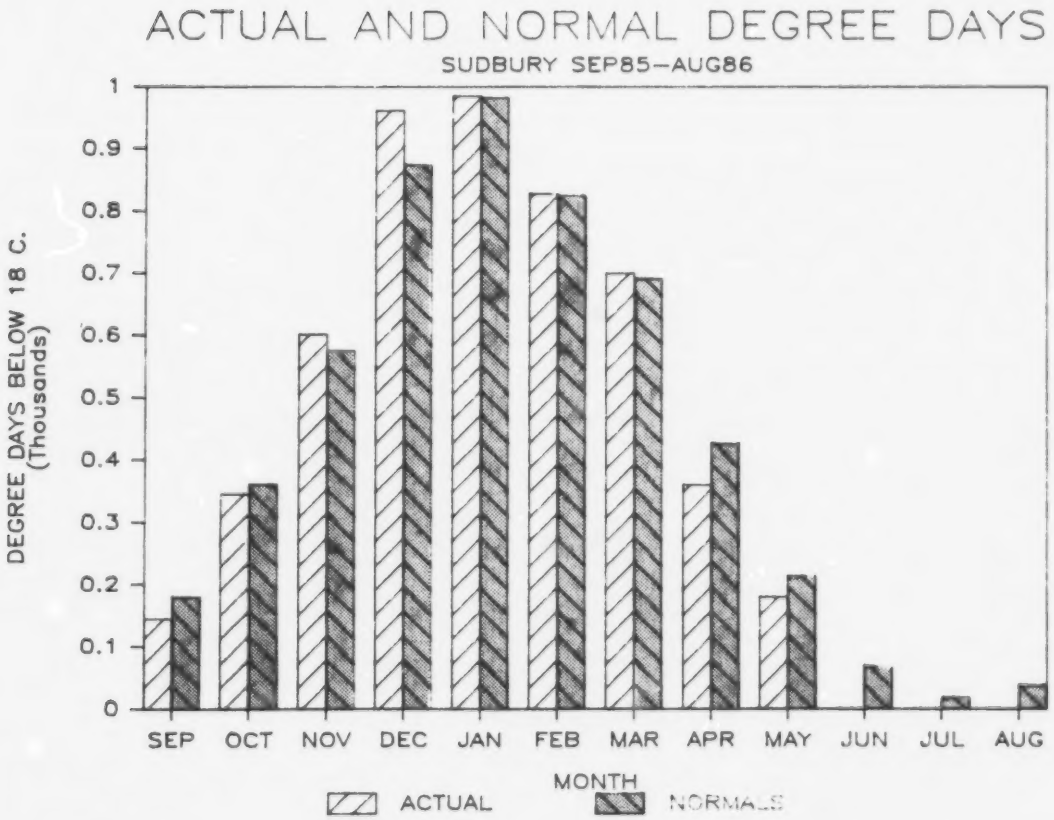
APPENDIX C

WEATHER DATA


ACTUAL AND NORMAL DEGREE DAYS
TORONTO SEP85–AUG86
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
MONTH
ACTUAL
NORMALS


ACTUAL AND NORMAL DEGREE DAYS
KINGSTON SEP85–AUG86
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
MONTH
ACTUAL
NORMALS


ACTUAL AND NORMAL DEGREE DAYS
ST.CATHERINES SEP85–AUG86
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
MONTH
ACTUAL
NORMALS


ACTUAL AND NORMAL DEGREE DAYS
SUDBURY SEP85–AUG86
DEGREE DAYS BELOW 18 C.
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
MONTH
ACTUAL
NORMALS

APPENDIX D

SAMPLE HOTCAN COMPUTER SIMULATION OUTPUT

```
* * * * * * * * * * * * * * * * * * * * *
*                HOTCAN!                  *
* NATIONAL RESEARCH COUNCIL OF CANADA     *
*    DIVISION OF BUILDING RESEARCH        *
*    SASKATOON, SASKATCHEWAN, 1982        *
*        (RELEASE HOTCAN 4.01)            *
* * * * * * * * * * * * * * * * * * * * *
```

CLIENT NAME:
ADDRESS : SUDBURY, ONTARIO

USER DATA FILE NAME:

DATA IS FOR SUDBURY

*** BUILDING PARAMETERS ***

ELEMENTS	HOUSE VOLUME	AIR CHANGE	HT LOSS W/DEGC	% SEASONAL HT LOSS
VENTILATION	18938 FT3	.19/HR	30.61	21.84
	AREA FT2	R VALUE FT2-DEGC/W		
CEILING	1172.65	45.00		
TOTAL	1172.65	45.00	13.75	9.81
MAIN WALLS	1040.30	28.00		
	96.82	28.00		
TOTAL	1137.12	28.00	21.43	15.29
DOORS	37.80	14.00		
TOTAL	37.80	14.00	1.42	1.02
BASEMENT AB.GD	312.70	20.00		
TOTAL	312.70	20.00	8.25	5.89
BASEMENT 2FT	278.52	20.00		
TOTAL	278.52	20.00	5.81	2.84
BASE. TO FLOOR	453.45	20.00		
TOTAL	453.45	20.00	7.03	3.44
FLOOR PERIMETER	402.78	.00		
TOTAL	402.78	.00	27.14	13.27
FLOOR CENTRE	763.17	.00		
TOTAL	763.17	.00	15.96	7.80
SOUTH WINDOWS	28.35	2.16		
	20.80	2.16		
TOTAL	49.15	2.16	12.01	8.57
NORTH WINDOWS	40.00	2.51		
TOTAL	40.00	2.51	8.42	6.01
EAST WINDOWS	24.20	2.16		
TOTAL	24.20	2.16	5.91	4.22

WEST WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00
S-EAST WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00
S-WEST WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00

ADDRESS : SUDBURY, ONTARIO

DESIGN HEAT LOSS AT -28C = 5.8 KW
DEGREE DAYS FOR SUDBURY IS 5447
TEMPERATURES (DEG C) MAIN FLOOR = 21 BASEMENT = 18
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 3.2
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 14
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 14
MASS LEVEL CHOSEN IS (A)
BASEMENT INSULATED PRIMARILY FROM THE INSIDE
WINDOW SHADING COEFFICIENTS: SOUTH = .89 NORTH = .89
EAST = .89 WEST = 0
S-EAST = 0 S-WEST = 0
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 4.75 FT
AVERAGE OVERHANG WIDTH = 1 FT
AVERAGE HEIGHT ABOVE WINDOW = .5 FT
NATURAL INFILTRATION RATE (AC/HR) = .05
FORCED VENTILATION RATE (AC/HR) = .45
HEAT RECOVERY EFFECTIVENESS ON VENTILATION AIR = 70 %

*** MONTHLY SUMMARY OF ENERGY CONSUMPTION ***

MONTH	THERMAL LOAD KWH/D	MONTHLY SOLAR FRAC	AUX HEAT REQ KWH/D	TOT CONS KWH/D
JAN	83.61	.19	68.00	96.00
FEB	81.76	.26	60.75	88.75
MAR	65.79	.33	43.84	71.84
APR	43.29	.42	25.31	53.31
MAY	22.18	.62	8.44	36.44
JUN	6.41	1.00	.00	28.00
JUL	.00	1.00	.00	28.00
AUG	.18	1.00	.00	28.00
SEP	12.73	.87	1.60	29.60
OCT	28.39	.43	16.28	44.28
NOV	48.77	.20	38.92	66.92
DEC	73.09	.17	60.45	88.45

*** YEARLY ENERGY CONSUMPTION COMPARISONS ***

12 MONTH HEATING SEASON IN EFFECT
ANNUAL SOLAR HEATING CONTRIBUTION = 31 %

ESTIMATED ANNUAL SPACE HEATING 35 GJ, OR 9,782 KWHRS
SEEH PROGRAM ENERGY BUDGET FOR SPACE HEATING = 9,836 KWHRS

PREDICTED ANNUAL AUXILIARY ENERGY CONSUMPTION = 10,220 KWHRS
SEEH PROGRAM AUXILIARY ENERGY CONSUMPTION = 10,600 KWHRS

TOTAL ANNUAL ENERGY CONSUMPTION = 20,002 KWHRS
TOTAL ANNUAL SEEH PROGRAM ENERGY BUDGET = 20,436 KWHRS

*** ANNUAL PREDICTED FUEL COSTS ***

FUEL COSTS ARE FOR ONTARIO AS OF 84/10/10

ENERGY SOURCE	COST PER UNIT	SPACE HEATING	HOT WATER	LIGHTS AND APPLIANCES
ELECTRICITY	5C/KWH	$ 489.13/YR EFF.= 100%	$ 255.5/YR EFF.= 100%	$ 255.5/YR EFF.= 100%

****

This estimate of energy demand may not reflect actual energy requirements of a house due to variations in weather, performance of equipment, and the lifestyle of the occupants.

****

APPENDIX E

CHAMBER STUDY

APPENDIX E CHAMBER STUDY

The need to determine the average carbon monoxide and carbon dioxide concentrations in the housing units being monitored led to a decision to attempt the use of Drager diffusion samplers for this purpose. The available Drager diffusion samplers are intended for eight hour exposures at relatively high concentrations of carbon monoxide or carbon dioxide. It was felt that, at lower concentrations, these samplers should be suitable for one week exposures in residential environments, if the appropriate calibration curves could be produced. The major incentive for exploring this possibility was the lack of any suitable time-averaged monitoring equipment which did not require the support of a data acquisition system.

In order to produce calibration curves for the Drager sample tubes, it is necessary to have a controlled environmental chamber capable of simulating the range of conditions expected in a residential environment. The basic required conditions include controlled concentrations of carbon monoxide between 0 and 25 parts per million, carbon dioxide between 300 and 2,000 parts per million, relative humidities between 20 and 80 percent, and temperatures between 15 ^{o}C and 30 ^{o}C. An additional requirement is that the flow rates throught the test chamber be relatively low so as not to affect the diffusion principles on which these samplers work.

A test apparatus was designed and built to simulate the desired conditions. It includes a 0.15 cubic metre test section into which a controlled mixture of moist and dry air, carbon monoxide and carbon dioxide is introduced. The schematic for the air/gas injection system is shown in Figure E.1. Dry air is supplied from an air compressor through an air dryer, drawing the dew-point of the air down to approximately -40^{o}C. After passing through a regulator, the air stream is split, with one stream remaining at the -40^{o}C dew-point condition and the other stream raised to saturation through a heated air bubbler system. The remixing of these two air streams in the appropriate proportions allows the controlling of the relative humidity from approximately two percent to one hundred percent. Carbon monoxide and carbon dioxide are introduced from pressurized bottles. The pressures are reduced through pressure regulators and controlled by flow control valves through flow meters. By mixing the concentrations of dry air, saturated air, carbon monoxide and carbon dioxide, air/gas mixtures can be obtained to meet any conditions within the desired ranges.

The appropriate gas mixture is fed into a test section in which the samplers for calibration are located. The temperature of the test section

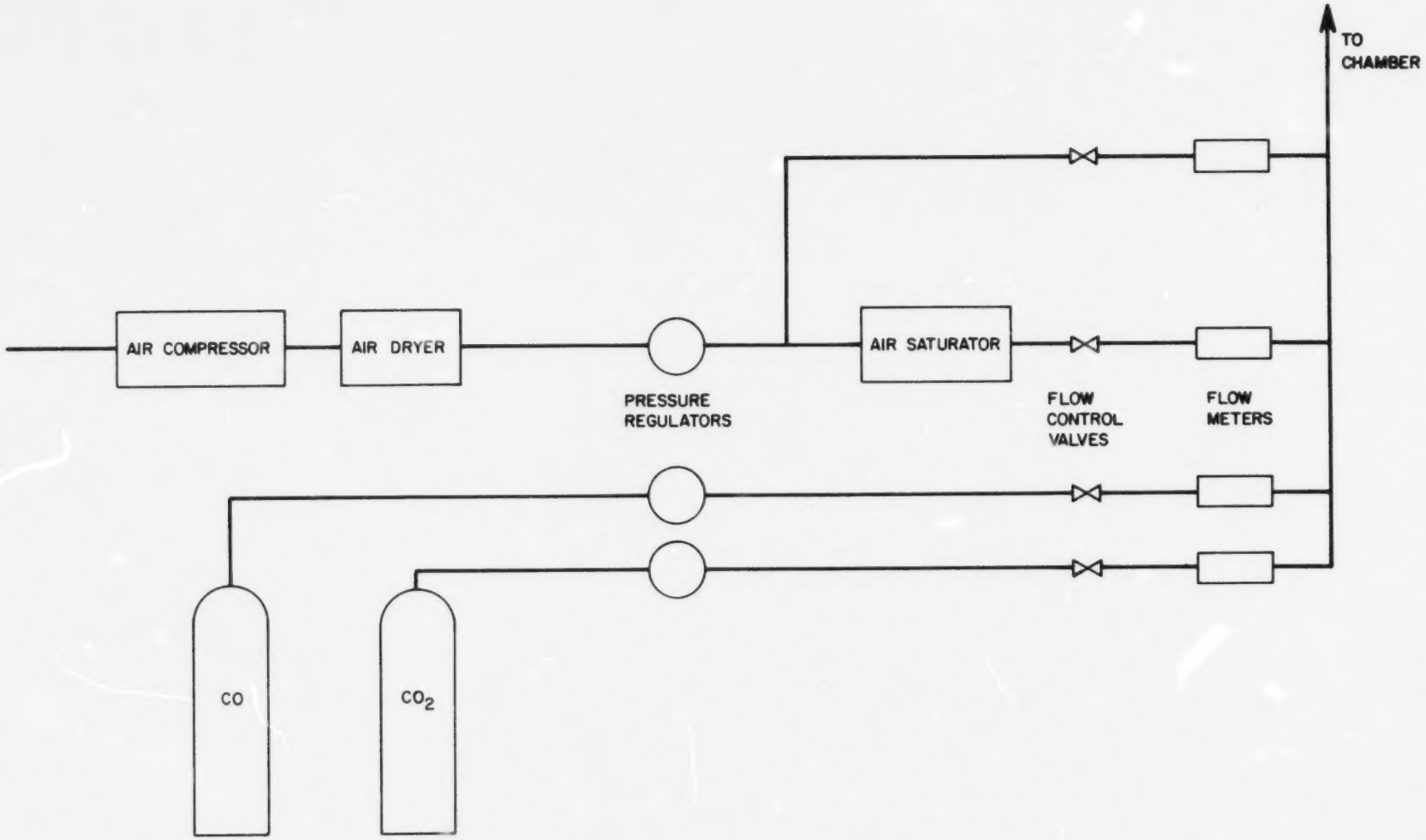

TO
CHAMBER
AIR COMPRESSOR
AIR DRYER
PRESSURE
REGULATORS
AIR SATURATOR
FLOW
CONTROL
VALVES
FLOW
METERS
CO
CO_2

Figure E.1

is maintained by locating the test section in a larger, outer temperature controlled chamber. A schematic of the test section is shown in Figure E.2. The air/gas mixture is fed through a heat exchanger coil in the outer temperature controlled chamber to stabilize its temperature before injection into the test cell. The air/gas mixture from within the test section is bled to the atmosphere through an exhaust line. At that point samples are taken of the relative humidity, temperature, and gas concentrations.

Figures E.3 and E.4 show general views of the chamber set up. Figure E.5 shows the air dryer and bottled gas connections. The air compressor system is not shown. Figure E.6 is a view of the test section. Figure E.7 shows the instrumentation for the measurement of dew-point, temperature, carbon dioxide concentration and carbon monoxide concentration in the test section. Figure E.8 shows the computer system used for on line data recording.

Due to the time required for the parts acquisition, construction, and commissioning of the test chamber apparatus, only the preliminary calibration curves for the Drager carbon dioxide diffusion samplers have been produced. These preliminary calibration curves have been used in the conversion of data in this report.

The initial results indicate extremely good stability and repeatability for the samplers. However, significant work is yet to be done in determining the precise dependence of readings on humidity and temperature conditions.

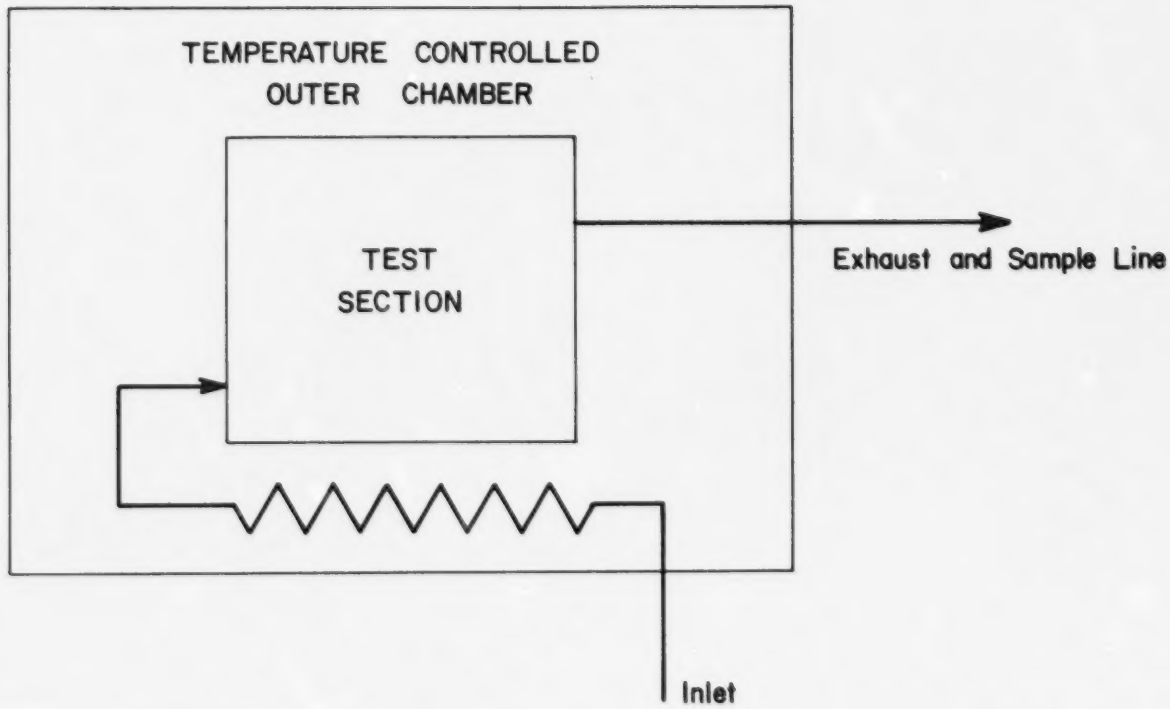

TEMPERATURE CONTROLLED
OUTER CHAMBER
TEST
SECTION
Exhaust and Sample Line
Inlet

Figure E2

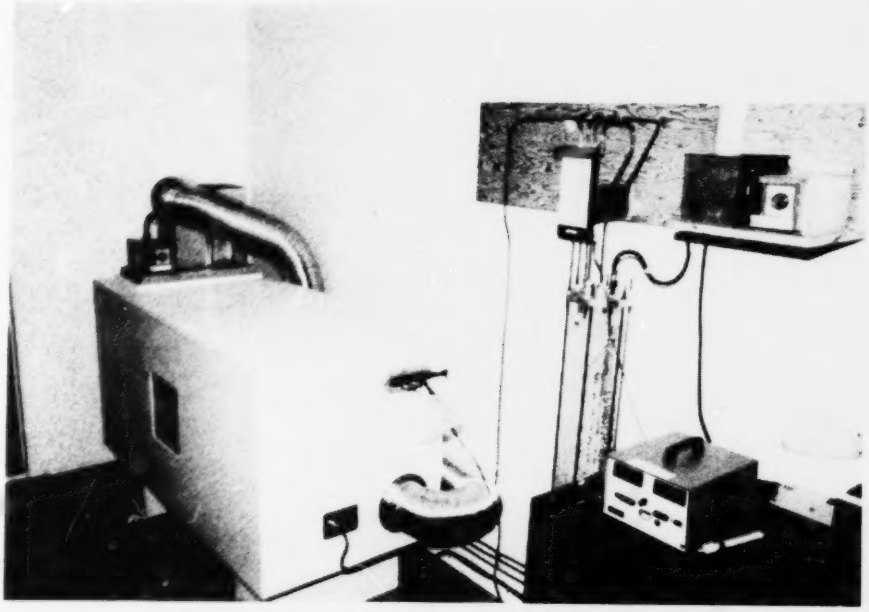


FIGURE E.3
GENERAL VIEW OF THE CHAMBER SET UP

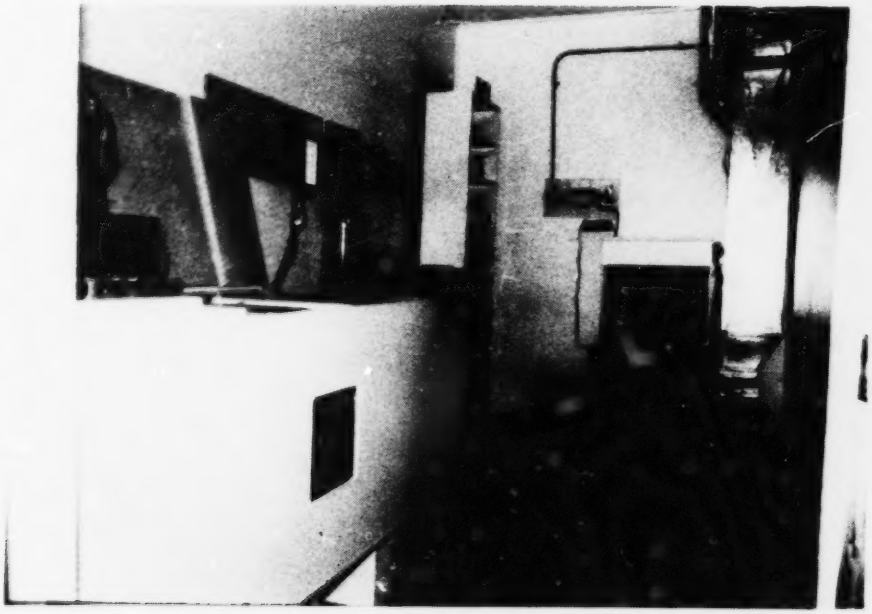
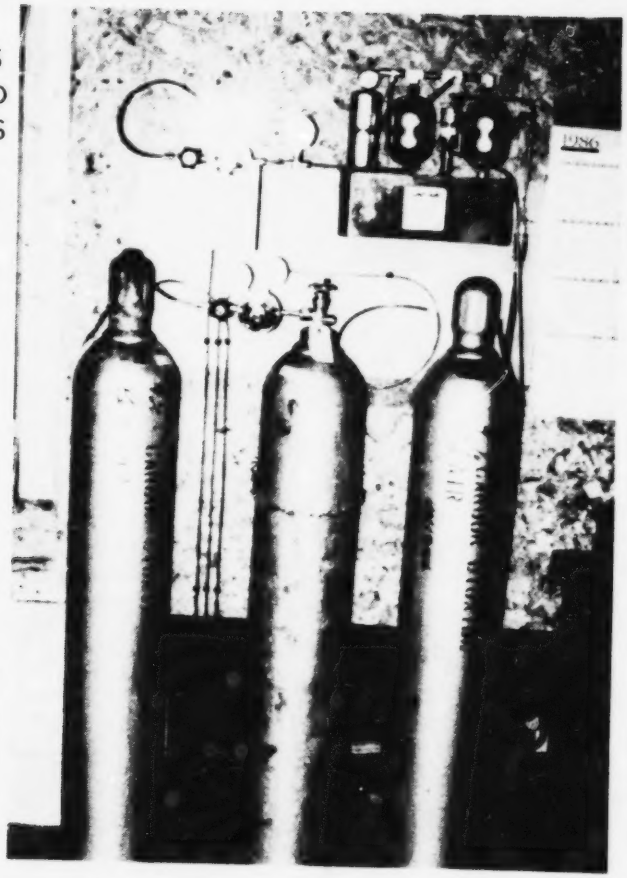
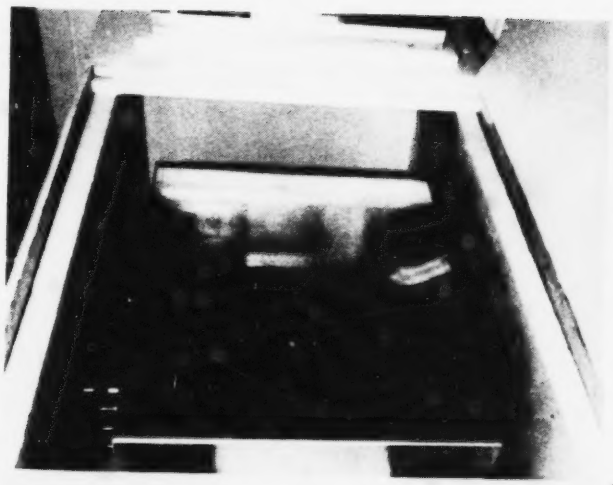


FIGURE E.4
GENERAL VIEW OF THE CHAMBER SET UP

FIGURE E.5
AIR DRYER AND
BOTTLED GAS CONNECTIONS





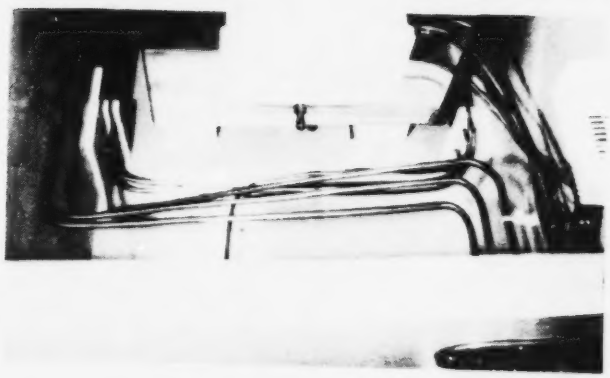


FIGURE E.6
VIEW OF TEST SECTION

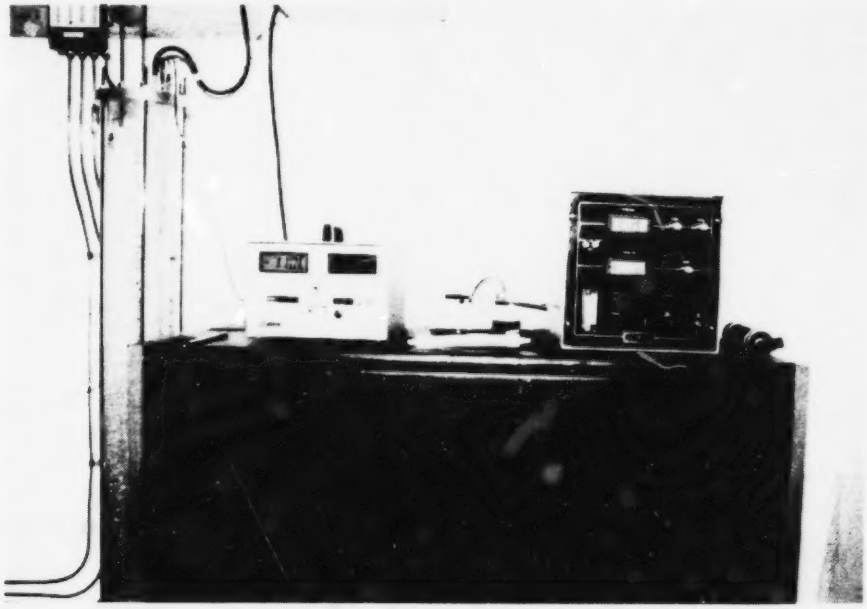


FIGURE E.7
INSTRUMENTATION FOR THE MEASUREMENT OF DEW POINT TEMPERATURE, CARBON DIOXIDE AND CARBON MONOXIDE CONCENTRATIONS IN THE TEST SECTION

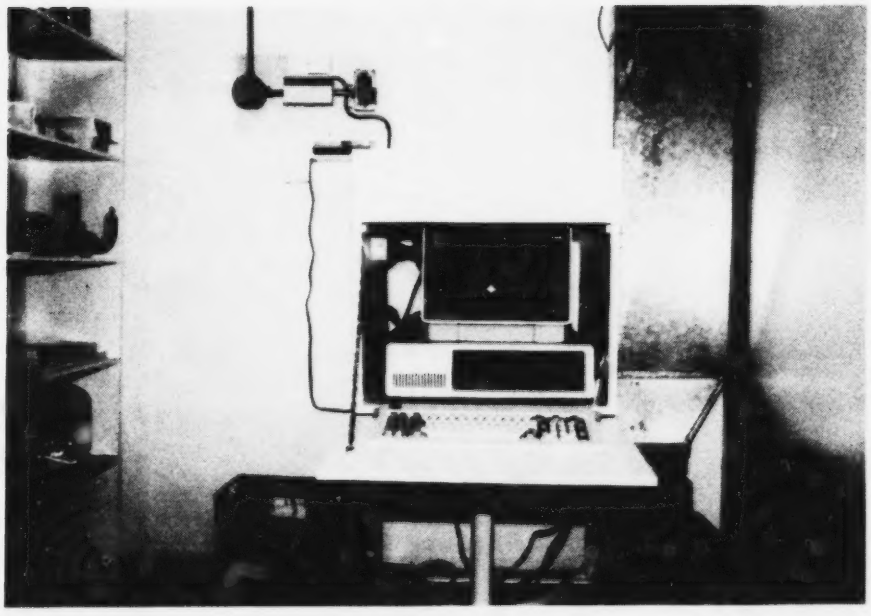


FIGURE E.8
COMPUTER SYSTEM USED FOR ONLINE DATA RECORDING

APPENDIX F

SAMPLE QUESTIONNAIRES

R-2000 HOME PROGRAM HOUSE NO. _____

HOME OCCUPANT QUESTIONNAIRE

DD MM YY

A: HOUSE LOCATION AND MAILING INFORMATION

1. _____ 2. _____
Name of Occupant Work Telephone number

3. _____ 4. _____
Name of Spouse Work telephone number

5. _____
House Street Address or Lot & Concession No.

6. _____ 7. _____
Municipality Province

8. _____ 9. _____
Postal Code Telephone Number

Mailing Address if different from House Address:

10. _____
Street Address or Lot & Concession No.

11. _____ 12. _____ 13. _____
Municipality Province Postal Code

14. Date Occupied: _____ 15. Is the occupant: HOMEOWNER RENTER

16. Original occupant? ☐ YES ☐ NO

If a new occupant has occupied the home since the previous visit you are required to complete a new "HOME OCCUPANT QUESTIONNAIRE."

B: HOME OCCUPANT PROFILE

17. No. of Adult Occupants (18+) ____ 18. No. of Children (under 18) ____

19. No. of Occupants who smoke: Cigarettes: _____ Cigars: _____ Pipe: _____

20. Age of:
Homeowner: 18 - 30 ☐ 31 - 45 ☐ 46 - 60 ☐ over 60 ☐

21. Spouse: 18 - 30 ☐ 31 - 45 ☐ 46 - 60 ☐ over 60 ☐

22. What do you and your spouse do for a living?

	HOMEOWNER	SPOUSE
Professional	☐	☐
Manager or Administrator	☐	☐
Technical	☐	☐
Sales	☐	☐
Clerical	☐	☐
Trades	☐	☐
Homemaker	☐	☐
Student	☐	☐
Retired	☐	☐
Other (specify)	☐	☐

23. How many occupants remain at home most of the day? Adults: _____ Children: _____

24. Was your previous residence (check one):

An apartment ☐ A row (garden home/townhouse) ☐

A semi-detached home ☐ A link single ☐ A detached home ☐

25. Did you own or rent your previous residence? owned ☐ (go to #27) rented ☐

26. If you rented, did you pay the following utilities?

	PAID DIRECTLY	INCLUDED IN RENT	DON'T KNOW
Space Heating	☐	☐	☐
Water Heating	☐	☐	☐
Electricity (other than for water and space heating)	☐	☐	☐
Other _____ (please specify)	☐	☐	☐

27. For how many years do you expect to occupy your new home?

Less than 5 years ☐ 21 - 25 years ☐

6 - 10 years ☐ more than 25 years ☐

11 - 15 years ☐ don't know ☐

16 - 20 years ☐

Renters go to Question #34

28. At the time you decided to purchase your present home how important were the following factors:

Factor	Not at all imp.	Somewhat important	Extremely important
Location	☐	☐	☐
Size and Design of Home	☐	☐	☐
Energy Costs	☐	☐	☐
Solar Orientation	☐	☐	☐
View	☐	☐	☐
Total Cost	☐	☐	☐
Downpayment	☐	☐	☐
Monthly P. I. T.	☐	☐	☐
Maintenance	☐	☐	☐
Higher resale	☐	☐	☐

29. What was the purchase price of your home? (optional) _____

30. Did you pay a premium for the energy efficient features in this home?

☐ YES (continue) ☐ NO (go to #32) ☐ DON'T KNOW (go to #32)

31. Over what period of time do you expect to recover the extra purchase price?

☐ within 2 years ☐ within 5 years ☐ within 10 years

☐ within 15 years ☐ never ☐ don't know

32. In assessing the affordability of this home, did you calculate your anticipated monthly payments for Principal, Interest Taxes and Energy (P.I.T.E.)?

YES ☐ NO ☐ DON'T KNOW ☐

33. Did your mortgage financing institution take energy costs into consideration when financing this home?

YES ☐ NO ☐ DON'T KNOW ☐

34. Do you expect energy costs to increase, decrease or remain about the same in the future?

	Over the next 5 years	Over the next 10 years
Expect significant increase (25%+)	☐	☐
Expect them to remain the same	☐	☐
Expect significant decrease (25%+)	☐	☐
Don't know	☐	☐

35. Are there any advantages or disadvantages to living in an energy efficient home?

Advantages: _____

_____

_____

_____

36. Disadvantages: _____

_____

_____

_____

_____

Renters go to Question #39

37. Which information source initially lead you towards your purchase of this home?

☐ Builder advertising ☐ Government information

☐ Newspaper articles ☐ Television advertising/features

☐ Friends ☐ Other: specify

38. Would you buy another R-2000 home if you sold this present one?

☐ YES ☐ NO ☐ DON'T KNOW

39. How many friends or acquaintances have become interested in R-2000 home construction as a result of your experience? _____

Lifestyle

40. Number of bathrooms: _____

41. Average number of tub-baths per week _____ (total family)

42. Average number of showers per week _____ (total family)

43. Specify any aspects of the occupants lifestyle that would use excessive amounts of energy (windows/door left open, overheated rooms, etc.)

_____

_____

_____

Technical Knowledge

	YES	NO	NA
44. Does the occupant know how to adjust thermostat settings?	☐	☐	☐
45. Does the occupant know how to adjust water heater temperature settings?	☐	☐	☐

46. Does the occupant operate the ventilation system when operating an air conditioner? ☐ YES ☐ NO ☐ NA

	Continuous	Intermittent (days/year)	NA
47. How often does the occupant operate the:			
humidifier	☐	☐	☐
air cleaning equipment	☐	☐	☐
ventilator in the summer	☐	☐	☐
ventilator in the winter	☐	☐	☐

48. How often does the occupant: clean the HRV filters (if applic.): _____

clean the HRV core (if applic.): _____

49. Does the occupant adjust the humidistat setting? ☐ YES ☐ NO ☐ NA

50. Has a manual been provided for operation and maintenance of the ventilation system? ☐ YES ☐ NO ☐ NA

NOTES (use reverse side if additional space is required)

R-2000 HOME PROGRAM HOME NO. _____

INITIAL ON-SITE VISIT REPORT

DD MM YY

Attached Spaces

1. Does the home include:

	UNHEATED	HEATING SYSTEM
Attached sunspace	☐	☐
Attached garage	☐	☐
Other attached space (Specify)	☐	☐

2. Is the attached space HEATED by:

☐ Portable heater: specify fuel _____

☐ Wood stove ☐ Passive Solar ☐ Primary Heating System

☐ Secondary Heating System ☐ House Exhaust air

Space Heating System Thermostats

3. Thermostat Location: (#1 primary, #2 secondary, #3 other)

	#1	#2	#3		#1	#2	#3
Living Room	☐	☐	☐	Den	☐	☐	☐
Dining Room	☐	☐	☐	Bedroom	☐	☐	☐
Main Floor Hallway	☐	☐	☐	Kitchen	☐	☐	☐
Upper Floor Hallway	☐	☐	☐	Basement	☐	☐	☐

Other: specify _____

4. Type of thermostat:

	#1	#2	#3
Simple	☐	☐	☐
Set-back	☐	☐	☐
Multi-cycle	☐	☐	☐

Air Conditioning Equipment

5. Is there air conditioning equipment installed? ☐ YES ☐ NO (go to #10)

6. Number of units ☐ Central ☐ Window

7. Cooling capacity (total for central, per unit for window) _____ (BTU's/hr)

8. Energuide No. (if applicable) _____

9. Installation: ☐ Builder ☐ Occupant ☐ Other _____

Humidifier

10. Is there a humidifier installed? ☐ YES ☐ NO (go to #14)

11. Humidifier location:

☐ Basement (stand alone type) ☐ Basement (combined with furnace)

☐ Main living area ☐ Combined with ventilation

☐ Other (specify) _____

12. Where is the humidifier control located:

☐ On the unit ☐ Main living area ☐ Other (specify) _____

13. What is the humidifier control setting: _____ % Rh

Air Cleaning Equipment

14. Is there air cleaning equipment? ☐ YES ☐ NO (go to #17)

15. Air cleaning equipment location:

☐ Furnace warm air duct ☐ Furnace humidifier

☐ Separate central unit ☐ Small room units specify rooms

16. Equipment operation: ☐ Continuous ☐ Intermittent

Appliances and Other Energy Consuming Equipment

17. If no appliances are installed, then go to #19.

	Fuel		Manufacturer	Energuide Value (kWh/month)	Supplier	
	Gas	Elec.			B.	O.
Radiant Oven						
Convection Oven						
Microwave Oven						
Refrigerator						
Freezer						
Dishwasher						
Wringer Washer						
Automatic Washer						
Clothes Dryer						

19. Specify any features that would lead to higher energy consumption.

1.

2.

Dishwasher

20. Is there a dishwasher installed? ☐ YES ☐ NO (go to #23)

21. In-line water heater installed? ☐ ☐

22. Drying method? ☐ Electric ☐ Door closed ☐ Doors open

Kitchen Range

23. What type of kitchen range hood is installed? ☐ None (go to #26)
☐ Recirculating (go to #25)
☐ Outdoor exhausting type

24. Where are range hood fumes exhausted?

☐ directly outdoors ☐ to heat recovery ventilator

☐ to furnace cold air return ☐ other (specify)_____

25. Does the range hood have a grease filter? YES ☐ NO ☐

Bathing

26. Water saving devices installed? ☐ YES ☐ NO ☐ DON'T KNOW

27. If YES specify the types:_____

_____

_____

Space Heating: Central Primary Heating System

28. Is there a central heating system installed? ☐ YES ☐ NO (go to #38)

29. Manufacturer: _____

30. Model Name and No. _____

31. Fuel: ☐ Oil ☐ Natural Gas ☐ Electric ☐ Propane ☐ Wood ☐ Solar

32. Heat Input (kW or BTU): _____ Output (kW or BTU): _____

33. Heat Distribution: ☐ Forced Air ☐ Gravity Air ☐ Forced Water

34. Where are cold air returns located? ☐ None installed ☐ Not Applicable

☐ Bedrooms ☐ Halls ☐ Kitchen ☐ Living Room ☐ Dining Room

35. Combustion air supply required? ☐ YES ☐ NO (go to #38)

36. Combustion air supply installed? ☐ YES ☐ NO (go to #38)

37. Combustion air supply dimensions (inches/cm)

Diameter (Cross-section) Distance to Combustion Appliance Location of Dump

_____ _____ _____

Space Heating: Baseboard Electric Heating

38. Is there baseboard electric heating installed? ☐ YES ☐ NO (go to #40)

39. If central heating exists with supplementary baseboard electric, where are baseboard heaters located:

_____

Additional Combustion Space Heating (Wood stoves, fireplaces, space heaters)

40. Enter up to 3 combustion space heating systems (if none exist go to #44)

	System #1	System #2	System #3
System Type			
Location			
Fuel			
Manufacturer			
Model			
Features			

41. Combustion air supply dimensions (inches or cm) circle applicable units

SYSTEM	DIAMETER (Cross Section)	DISTANCE (to combustion chamber)	OBSTRUCTED SUPPLY (Y/N)
#1			
#2			
#3			

42. Chimney Type: ☐ Masonry ☐ Metal Insulated ☐ Metal Non-Insulated

43. Chimney Location: ☐ Interior wall ☐ Exterior wall

Water Heating

Primary Domestic Water Heating System

44. Water Heater Manufacturer: _____ 45. Model No. _____

46. Fuel: ☐ Oil ☐ Natural Gas ☐ Electric ☐ Propane ☐ Wood ☐ Solar

47. Has extra insulation been added to:

	YES	NO	NA
tank	☐	☐	☐
pipes	☐	☐	☐
heat trap	☐	☐	☐

48. Water heater temperature setting: _____

49. Can combustion air supply be easily obstructed (if applic.) ☐ YES ☐ NO

Secondary Domestic Water Heating System

50. Water Heater Manufacturer: _____ 45. Model No. _____

51. Fuel: ☐ Oil ☐ Natural Gas ☐ Electric ☐ Propane ☐ Wood ☐ Solar

52. Has extra insulation been added to:

	YES	NO	NA
tank	☐	☐	☐
pipes	☐	☐	☐
heat trap	☐	☐	☐

53. Water heater temperature setting: _____

Additional Water Heating Features

	YES	NO	NA
54. Is a pre-heat water tank installed?	☐	☐	☐
55. Is a grey water heat recovery system installed?	☐	☐	☐

56. If YES to #55, then specify: Manufacturer: _____

Model: _____ Approximate Heat Recovery (%): _____

Clothes Dryer

57. Is there a clothes dryer? ☐ YES ☐ NO (go to #60)

58. Where is the clothes dryer exhaust air ducted:

☐ directly to exterior ☐ to the basement air space

☐ to HRV supply duct ☐ to HRV exhaust duct

☐ to furnace cold air return ☐ other (specify) _____

59. Is there an extrs lint-trap? ☐ YES ☐ NO ☐ NA

Basement Inspection

60. Is the basement finished ☐ YES (%)_____ ☐ NO ☐ NA

61. Basement Floor: ☐ Exposed (%)_____ ☐ Tiled ☐ Carpeted

62. Floor header area insulation: ☐ YES ☐ NO ☐ NA

	Fibreglass	Rigid (type)	
	☐		
Vapour barrier installed	☐	☐	☐
Vapour barrier sealed	☐	☐	☐

63. Basement wall insulation: ☐ Inside ☐ Outside ☐ None ☐ NA

64. High basement humidity during summer? ☐ YES ☐ NO ☐ NA

South, Southeast and Southwest Window Coverings

65. Identify the rooms (south, southeast, southwest) which contain coverings, and place a check mark in the appropriate covering type.

Room	Insulated Shutters	Drapes				Blinds	
		Opaque	Semi-opaque	Transparant	Insul.	Vert.	Venetian

66. Average number of hours per day closed: _____

Electrical Use: Outside of Building Space

67. Vehicle block heater used? ☐ YES ☐ NO
If YES,
hours/day _____ X number of vehicles ____ X days/ year ____

68. Neighbouring building or workshop (not within the heated space) electrical use? ☐ YES ☐ NO

69. Other (specify) _____

House Equipment Checklist

FEATURE	MISSING/PROBLEM
Kitchen range hood grease filter	_____
Clothes dryer extra lint filter (vented inside)	_____
Dehumidifier condensate drain hose	_____
Variable speed control on continuous furnace fan	_____
Filters for furnace	_____
Cold air returns in: _____	_____
Warm air supplies in: _____	_____
Weatherstripping or gasketting of doors	_____
Caulking and sealing of windows	_____
Floor header area insulated	_____

Description of Problem: _____

Description of Problem: _____

ADDITIONAL NOTES/PROBLEMS

R-2000 HOME PROGRAM HOUSE NO. _____

VENTILATION SYSTEM REPORT

DD MM YY

Ventilation Equipment (with or without heat recovery)

1. Type of Ventilator:

☐ Ventilation Fans ☐ Heat Pump ☐ Heat Pipe

☐ Whole House Ventilator (no heat recovery) ☐ Heat Recovery Ventilator

2. Manufacturer: (excluding ventilation fans) _____

3. Model: _____ 4. Serial No. _____

5. Ventilator location: _____

6. Where is supply air dumped:

☐	basement air space directly			
☐	main living space discharge: (specify rooms, if not distributed via forced air heating system)	floor	mid-wall	ceiling
☐	furnace cold air return: ☐ direct connection ☐ damper installed			
☐	near furnace cold air return: indirect connection ☐ damper installed (distance to cold air return = _____)			
☐	other: (describe) _____			

7. If supply air is <u>not</u> integrated with forced air heating system, how is fresh air tempered?

☐ duct heater ☐ HRV preheater ☐ discharge at baseboard heaters

8. Location of ventilation system stale air points or exhaust fans: Place a "V" in the box if connected to ventilator; place an "O" in box if direct outside ventilation, Place the number of exhaust points beside the location, if more than 1 are observed

☐ Bathroom ☐ Kitchen ☐ Laundry

☐ Bedrooms ☐ Living Room ☐ Dining Room

☐ Basement ☐ Hallway ☐ Other (specify)

_____

9. Any additional equipment with separate exhaust? ☐ YES ☐ NO (go to #11)

10. Type of exhaust equipment

☐ Clothes dryer (outdoor venting) Location : _____
☐ Central vaccuum _____
☐ Direct vented cook-top unit _____
☐ Others (specify) _____ _____

	NA	YES	NO
11. Clothes dryer ducted to, or near ventilator:	☐	☐	☐
12. Basement air space ventilated via ventilator:	☐	☐	☐

13. Humidistat controls: Setting (% RH)

☐ on unit _____

☐ living area: location _____ _____

☐ other: (specify) _____ _____

14. Controls with ventilation equipment:

☐ Manual On/Off switch Location: _____

☐ Interval Timer Location: _____

☐ Variable speed switch Location: _____

☐ Booster fan switch Location: _____

☐ Other _____ Location: _____

15. Additional ventilation booster fans installed? ☐ YES ☐ NO

Speed (cfm or l/s)	Location
_____	_____
_____	_____

Heat Recovery Ventilators Only

16. Indicate the approximate length of duct runs and the number of right angle turns (in all directions) in the duct runs; indicate whether the duct runs are insulated and are wrapped with a vapour barrier and if there exists a fabric type connection to the HRV:

	Length (ft.)	# of 90 angles	Insulated Duct (Y/N)	Vapour Barrier (Y/N)	Fabric Connection (Y/N)
Stale air warm side	_____	_____	_____	_____	_____
Stale air cold side	_____	_____	_____	_____	_____
Fresh air warm side	_____	_____	_____	_____	_____
Fresh air cold side	_____	_____	_____	_____	_____

		YES	NO	NA
17.	HRV Vibration Dampening Mounts installed:	☐	☐	☐
18.	Does the unit have: fan defrost cycle	☐	☐	☐
	electric preheater	☐	☐	☐

19. Have filters been installed? ☐ YES ☐ NO ☐ NA

20. If YES, location of filters: ☐ stale air duct ☐ fresh air duct
exhaust pickup grilles ☐ fresh air grille ☐ in HRV

21. Is fresh air intake port located where it may draw in contaminants such as near a driveway, gas valve or gas meter? ☐ YES ☐ NO

If YES: specify location and possible source: _____

---

22. Approximate height above grade of fresh air intake port: _____ ft. in. cm.

Place a check beside the missing items for the heat recovery ventilator. If the option is not available, then write NA where a check is required. If the features are installed, but are either poorly installed or malfunctioning, then specify the problem in the notes following this section and include this on the "REMEDIAL MEASURES IDENTIFICATION FORM"

Heat Recovery Ventilator Checklist

FEATURE	MISSING/PROBLEMS
Condensate drain hose	
Exterior duct insulation (to outside wall)	
Interior duct vapour barrier (to outside wall)	
Exterior port screens (bird screens)	
Exterior ports located at least 4 feet apart	
Interior ports are at least 2 feet above grade	
Sealing of exterior duct penetrations at header	
Filter on warm air side of HRV	
Humidistat control	
Stale air pickup in each bathroom	
Stale air pickup in kitchen	

Description of Problem: _____

_____

_____

NOTES: (use reverse side if additional space is required)

4.7 THE FOLLOW-UP HOMEOWNER SURVEY AND INSTRUCTIONS FOR COMPLETION

Most of the questions to be completed for the Follow-up Homeowner Survey are self-explanatory (SE). Where required additional explanations have been provided.

800-804 SE

805 If there has been a significant change of occupancy do not complete this questionnaire further. Instead complete the Homeowner Survey questionnaire.

806-808 SE

December 19, 1985

R-2000 HOME PROGRAM
FOLLOW-UP HOMEOWNER SURVEY

TO BE COMPLETED "ON-SITE" BY GT — FOR OFFICE USE

800. House Code _ - _____ - _____ 800. _____

801. OCCUPANT NAME: _____ _____ 801. _____
Surname Initial

802. PHONE: home: _____ 802. _____
803. work: _____ 803. _____
area code number

NOTE: WHERE APPROPRIATE, CIRCLE THE RIGHT ANSWER

804. Is this house an:

1 - R-2000 Demo 2 - R-2000 ID or repeat 3 - Comparative 804. _____

805. Original Occupant: 1 - YES 2 - NO 805. _____

IF YES: PROCEED TO NEXT QUESTION
IF NO: USE INITIAL HOMEOWNER SURVEY

FOR R-2000 ONLY COMPARATIVES PROCEED TO PG. #3

806. Do you view the energy features of your R-2000 home as:

1 - positive features
2 - negative features
3 - neither positive nor negative 806. _____

807. Has your R-2000 home realized the energy savings you expected from an R-2000 home?
1-YES 2-NO 3-PARTLY 807. _____
-1 N/A (for occupants not paying heating)

808. Did you realize that with the meters installed by your builder, you can monitor the energy required for space heating and domestic hot water separate from the energy required for lighting and appliances?
1-YES 2-NO 3-Meters not installed -1 N/A 808. _____

Comment:

809. (RESERVED) 809. R

811-818 It is important that the respondent volunteer information regarding perceived advantages or disadvantages of living in an R-2000 home. Do not prompt the respondent in any way.

819-820 Self Explanatory

810. (RESERVED) 810. R

Since we last visited your home, are there other aspects to consider when living in an R-2000 energy efficient home? (Do not prompt)

ADVANTAGES:

	02. None		
811.	11. Constant temperature	811.	
	12. Quieter		
812.	13. No drafts	812.	
	14. Warmer		
813.	15. Fresh air	813.	
	16. Better humidity		
814.	17. Less dust	814.	
	18. Less moisture		
	19. Other (specify) _____		

DISADVANTAGES:

	02. None		
815.	21. HRV noise	815.	
	22. Stale air		
816.	23. Loud furnace	816.	
	24. Air is too dry		
817.	25. Too much humidity	817.	
	26. Solar overheating		
818.	27. Cold basements	818.	
	28. Kitchen overheating		
	29. Other (specify) _____		

819. If you sold this R-2000 home, would you buy another R-2000 home?

1 - YES 2 - NO 3 - DON'T KNOW -1 N/A 819. _____

820. How many friends or acquaintances have become interested in R-2000 home construction as a result of your experience? _____ persons 820. _____

821. (RESERVED) 821. R

660-687 Identify only those major appliances that have been added, or changed, since the initial Homeowner Survey was completed.

The manufacturer and model of an appliance need only be identified if the Energuide Rating is unknown.

Refer to the footnote below question 686 for appropriate fuel codes.

Y OR APPLIANCES (Any additions or changes should be noted and added to the initial homeowner responses)

		Fuel*	Manufacturer and model (if energuide rating is unknown)	Energuide Value kWh/month
660.	Range (oven/stove)	660._____		661. _____
662.	Stove top	662._____		663. _____
664.	Oven (seperate)	664._____		665. _____
666.	Convection oven	666._____		667. _____
668.	Microwave oven	668._____		669. _____
670.	Refrigerator	670._____		671. _____
672.	Freezer	672._____		673. _____
4.	Dishwasher	674._____		675. _____
676.	Wringer washer	676._____		677. _____
678.	Automatic washer	678._____		679. _____
680.	Clothes dryer	680._____		681. _____
	Others (specify)			
682.	_____	682._____		683. _____
684.	_____	684._____		685. _____
686.	_____	686._____		687. _____

*Assume Electric (31) unless otherwise identified, gas (32) propane (33)

Comment:

F.H.S. 12/19/85

822-825 If the respondent identifies an added feature that would lead to higher energy consumption, confirm in the initial Homeowner Survey that this item was not already recorded (Questions 688-692).

826-830 Self Explanatory

833 Do not suggest possible problems or concerns or prompt the respondent in any way.

822. Specify any newly added features in the home that would lead to higher energy consumption. (confirm against #688-692)

20 - None
21 - Well pump
22 - Sump pump — 822. _____
23 - Sauna
24 - Workshop — 823. _____
25 - Indoor pool
26 - Whirpool — 824. _____
27 - Hobbies intensive in energy consumption e.g. pottery kiln
28 - Garbage compactor/shredder — 825. _____
29 - Central vacuum
09 - Other (specify) _____

826. Specify any lifestyle aspects that would impact on energy use not identified previously.

02 - None
31 - Open windows/doors
32 - Outdoor pool
33 - Electric lawnmower (garden tools) — 826. _____
34 - Yard lighting
35 - Separate workshop — 827. _____
36 - Heated walk/drive
37 - Hobby barn — 828. _____
09 - Other (specify) _____
_____ — 829. _____
_____

830. Since we last visited your house, are there areas attached to the home, which were not previously heated, and are now heated?

02 - None
06 - Addition
09 - Other (specify) _____
21 - Garage
24 - Workshop
54 - Sunspace
830. _____

832. (RESERVED) — 832. _____

833. Do you have any comments regarding air quality within the home? (Moisture, dry air, odours) (DO NOT PROMPT)

02 - None identified
51 - Moisture (humidity) Go to 834-844
52 - Odours Go to 846-850
53 - Odours and humidity Go to 834-850
54 - Dry (static) air Go to 852-856 — 833. _____

Comment:

.H.S. 12/19/85

Respond to only those questions that were identified as a problem in question 833. For example, if the respondent identified "odours" as a concern, then respond only to questions 846-850.

434-844 Ask the respondent to describe the home humidity conditions in his/her own terms.

846-850 Have the respondent describe the concerns in as much detail as possible including when the odours occur.

852-856 Ask the respondent to describe the dry/static air conditions in detail.

Please indicate the degree of the problem by placing a number under the appropriate column (summer, winter). (Do not prompt)

1 = minor, 2 = moderate, 3 = severe

ISTURE/HUMIDITY	SUMMER	WINTER	
	834	835	
834. window panes, sills and trim			834. _____
			835. _____
COMMENT: _____			
	836	837	
836. mildew in room ceiling corners			836. _____
			837. _____
COMMENT: _____			
	838	839	
838. sensory perception of moisture			838. _____
			839. _____
COMMENT: _____			
	840	841	
840. warped or swollen doors			840. _____
			841. _____
COMMENT: _____			
	842	843	
842. damp basement floors or walls			842. _____
			843. _____
COMMENT: _____			
	844	845	
\. Other (specify) _____			844. _____
			845. _____
COMMENT: _____			
DOURS			
	846	847	
846. In kitchen			846. _____
			847. _____
COMMENT: _____			
	848	849	
848. Bathroom			848. _____
			849. _____
COMMENT: _____			
	850	851	
850. Other (specify) _____			850. _____
			851. _____
COMMENT: _____			
DRY/STATIC AIR			
	852	853	
852. Sensory perception (eg. dry throat)			852. _____
			853. _____
COMMENT: _____			
	854	855	
854. Static electricity			854. _____
			855. _____
COMMENT: _____			
	856	857	
56. Other (specify) _____			856. _____
			857. _____
COMMENT:			

F.H.S. 12/19/85

858-865 Self Explanatory (SE)

867-872 If the answer is "no" to any of these questions explain the importance of properly maintaining and operating the equipment. Refer the homeowner to the equipment literature for official maintenance requirements and operating instructions.

875 SE

How often does the occupant operate the:
1 - Continuous 2 - Intermittant
3 - Present but not used -1 N/A

858.	humidifier _____	858.	_____
859.	dehumidifier _____	859.	_____
860.	electronic air cleaning equipment _____	860.	_____
861.	HRV in the summer _____	861.	_____
862.	HRV in the winter _____	862.	_____
863.	Furnace Blower in winter _____	863.	_____
864.	Furnace Blower in summer _____	864.	_____
865.	Air conditioning _____	865.	_____
866.	(RESERVED)	866.	R

Have you:
1 - YES 2 - NO -1 N/A

867.	cleaned the HRV filters _____	867.	_____
868.	cleaned the HRV core _____	868.	_____
869.	checked the HRV intake hood _____	869.	_____
870.	adjusted the dehumidistat setting _____	870.	_____
871.	changed the furnace filter _____	871.	_____
872.	cleaned the electronic air cleaner _____	872.	_____
873.	(RESERVED)	873.	R
874.	(RESERVED)	874.	R

875. Does the homeowner have any comments on the ventilation system? 875. R

_____ 876. R

_____ 877. R

_____

_____

878 If any new hobbies are identified at this time, confirm that this information was not already recorded in the initial Homeowner Survey, questions 729-732.

881 Refer to the responses to questions 733-740 in the initial Homeowner Survey before asking this question.

878. Do you have any new hobbies that could impact on interior air quality? (confirm #729-732)

02 - None
41 - Pottery/Crafts
42 - Wood working 878. _____
43 - Mechanical repairs
44 - Oil painting 879. _____
45 - Beer/wine making
46 - Furniture stripping/staining 880. _____
49 - Other (specify) _____

881. Last year when we visited your home, you identified that members of your family were sensitive/not sensitive to allergies and/or asthma (check #733-740). Has there been any change in this regard?

1-increased sensitivity 2-remained the same
3-decreased sensitivity 4-no comment
5-this question was not previously asked 881. _____

Comment:

882. (RESERVED) 882. R

883. Technician: _____ 883. _____
Last name, Initial

884. Date _____ _____ 884. _____
(MM/DD/YY) Signature

Time to Complete Questionnaire: _____ _____
Hrs. Mins.

General notes/comments: